MANUFACTURING TECHNOLOGY

(Diploma 4th SEM)

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MODULE-II

* Manufacturing Process.

→ The process of converting raw material, component or parts into finished goods that meet a customer expectation or specification.

It can broadly divided into two groups.

(a) Primary manufacturing process.
(b) Secondary manufacturing process.

(a) Primary manufacturing process.

→ Provide basic shape & size to the material as per designer's requirement.

* Liquid stage forming processes.
  e.g. casting. (manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of desired shape then allowed to solidify. The solidified part known as casting)
* Solid stage forming processes.
  e.g all metal working process forging, rolling, extrusion etc.
* Powder stage forming processes
  e.g powder metallurgy.

(b) Secondary manufacturing process.

→ To provide final shape & size with tighten control on dimension.

e.g surface characteristics.
material removal process.

This process can be divided into two groups

(1) Conventional machining process.
(2) Non conventional or Non traditional machining process.

① Conventional machining process.

→ Conventional machining processes mostly remove material in the form of chips by applying forces on the work piece material. e.g.- turning, Drilling, milling etc.

* The major characteristics of conventional machining are..:

(i) Generally macroscopic chip formation by shear deformation.

(ii) Material removal takes place due to application of cutting forces - energy domain can be classified as mechanical.

(iii) Cutting tool is harder than the work piece at room temperature as well as machining conditions.

② Non conventional machining process.

→ Non conventional machining process is defined as a group of processes that remove excess material by various techniques, involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for conventional manufacturing process.

* The major characteristics of Non conventional machining are:

(i) Material removal may occur with chip formation or even no chip formation may take place.

(*) For e.g. In AJM, chips are of microscopic size, & in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.

(ii) In NTM, there may not be a physical tool present.

(*) For e.g., In Laser Jet machining, machining is carried out by laser beam.

→ WJM, machining is done by a high pressure water jet.

→ EDM, a physical tool is very much required.

(iii) In NTM, the tool need not be harder than the workpiece material

(*) For e.g. - In EDM copper is used as the tool material to machine hardened steels.

Q1) Differentiate between Primary & Secondary manufacturing process?

Q2) Differentiate between Conventional & non conventional machining process?

* ~~Classification of~~ machining Process

→ During the manufacturing of a part, a variety of processes are needed to remove excess material.

e.g. Turning, Boring, Shaping, Planning → Single point cutting tool.

Milling, Drilling, Hobbing, Broaching → Multi point cutting tool.

→ Each processes plays a key role in how a product is manufactured & enhance each product's unique properties.

* Machine tool :-

→ A machine tool is a device powered by an external power source (motor, crank, steam engine, etc.) which holds a workpiece & a tool in place while manipulating them according to a path determined by the operator in order to re-shape the workpiece.

→ Machine tools are machines that give special forms to the materials in desired shapes & tolerances.

→ Machine tools are the kind of machines on which the metal cutting or metal forming processes are carried out, whereas machine is a device which converts one form of input into output.

* Main function of machine tool.

(i) To hold the tool.

(ii) To move the tool or the workpiece or both.

(iii) To supply required energy to cause metal cutting.

* Classification of machine tools.

① General purpose.

→ Lathe.
→ Drilling machine.
→ Shaping machine.
→ Planning machine.
→ Milling machine.

② Special purpose

→ special lathe like capsten, turret. & Copying lathe.
→ Boring machine.
→ Broaching machine.

③ Automatic machine tool.

→ These machine tools, also called automatic screw cutting machines, are used for mass production.

(4) Computer numeric control machine tool (CNC)

→ Under CNC machine tools, we have CNC turning centre, which does all the work of a Lathe & CNC machining centre which does milling, drilling etc. with provision for automatic tool changing.

* The LATHE

→ The lathe can be defined as a machine tool which holds the work between two rigid & strong support called centers. The cutting tool is rigidly held & supported in a tool post & fed against the revolving work while the work revolves about its own axis, the tool is made to move either parallel or at an inclination with this axis to cut the desired material.

* Function of the Lathe.

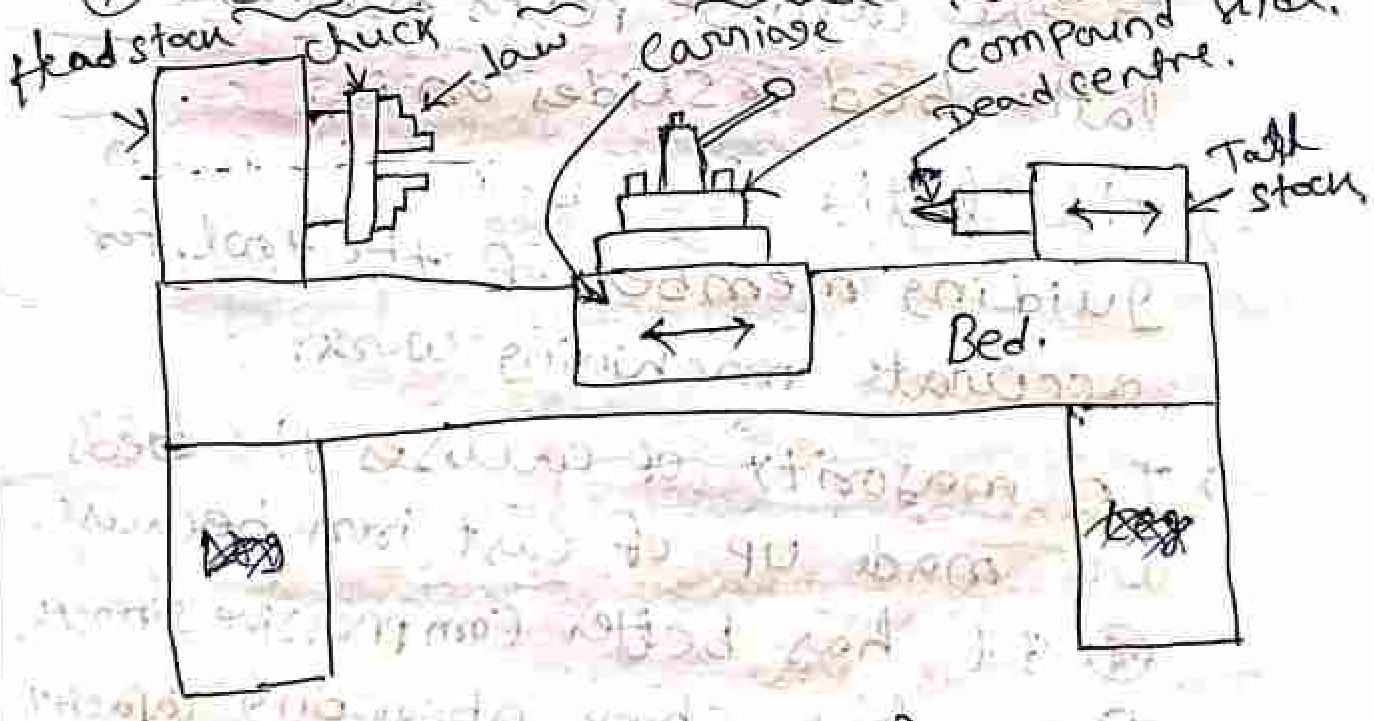
→ The main function of a Lathe is to remove metal from a piece of work to give it the required shape & size.

→ This's accomplished by holding the work securely & rigidly on the machine & then turning it against cutting tool which will remove metal from the work in the form of chips.

* Types of Lathe :-

(i) Engine or center lathe.
(ii) Speed Lathe.
(iii) Bench Lathe.
(iv) Tool room lathe.
(v) Turret & capstan Lathe.
(vi) Automatic lathe.
(vii) Special purpose lathe.

(i) Engine or center lathe :-



(Block diagram)

* Parts of a Lathe

1. Bed
2. Head stock
3. Tail stock
4. Carriage
5. ~~Legs.~~
5. Feed mechanism.

1. Bed:-

→ The lathe bed forms the base of the machine.

→ The headstock & the tailstock are located at either end of the bed & the carriage rests over the lathe bed & slides on it.

→ The lathe bed being the main guiding member of the tool, for accurate machining work.

→ In majority of causes the beds are made up of cast iron because.

(i) It has better compressive strength.
(ii) It has shock absorbing capacity.
(iii) It can easily be cast & machined.

② Head stock :

→ The headstock is permanently fastened at the left hand end of the bed, & it provides mechanical means of rotating the work at multiple speed. This is made of carbon or Nickel chrome steel.

→ This is usually of a large diameter to resist bending & it should be perfectly aligned with the lathe axis & accurately machined for producing true work surface.

→ It serves as a housing for the driving mechanism.

③ Tail stock or loose headstock

→ The tailstock is located on the innerways at the right hand end of the bed.

→ This has two main ~~cause~~ uses.

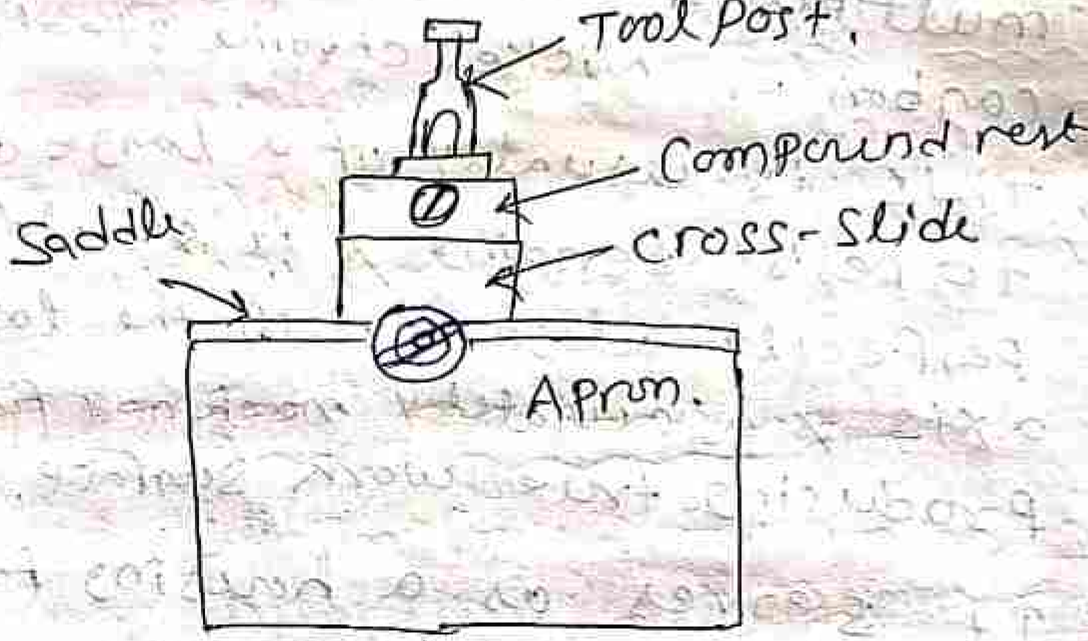
(i) It supports the other end of the work when it is being machined between centres.

(ii). It holds a tool for performing operations such as drilling, reaming, tapping, etc.

4. <u>carriage</u>:-

→ Carriage control & support the cutting ~~tools~~ tool.

→ It consists of five major parts.



(i) Saddle
(ii) cross slide
(iii) compound rest.
(iv) Tool post.
(v) Apron.

(i) <u>Saddle</u>:-

→ It is fits over the bed & slides along the way.

→ It carries the cross slide, compound rest & tool post.

→ Generally ~~is~~ provided for locking the saddle to prevent any movement when surfacing operation are carried ou

(ii) Cross slide:

→ It is mounted on the top of the saddle & always moves in a direction normal to the axis of the main spindle.

→ It can either be operated by hand, by means of the cross-feed screw.

(iii) Compound rest:

→ The compound rest is mounted on the top of the cross-slide & has a circular base graduated in degrees.

→ It is used for obtaining angular cuts & short tapers as well as convenient positioning of the tool to the work.

(iv) Tool post:

→ This is located on the top of the compound rest to hold the tool & to enable it to be adjusted to a convenient working position.

→ The type & mounting of the tool post depends upon the class of work for which it is to be used.

→ The rigidity of the tool holder & effective method of securing one the essential factors in designing a tool post.

(iv) Apron :-

→ The apron is fastened to the saddle & hangs over the front of the bed.

→ It contains gears, clutches, & levers for operating the carriage by hand & power feeds.

→ The apron also contains friction clutches for automatic feeds.

(5) Feed mechanism :-

→ It is employed for imparting various feeds (longitudinal, cross, & angular) to the cutting tool.

→ It consists of feed reverse lever, tumbler reversing mechanism, change gears, feed gear box, quick change gear box, lead screw, feed rod, apron mechanism & half-nut mechanism,

* Size & Specifications of Lathe

The following specifications are necessary to provide while ordering the Lathe:-

(i) The height of the center - measured from the lathe bed.

(ii) The swing diameter over bed.
This is largest diameter of work that will revolve without touching the bed.

(iii) The swing diameter over carriage
This is largest diameter of work that will revolve over the lathe saddle, & is always less than the swing diameter over the bed.

(iv) The length between centres.
This is the maximum length of work that can be mounted between the lathe centres.

(v) The maximum bar diameter.
This is the maximum diameter of bar stock that will pass through hole of the headstock spindle.

(vi) The length of bed.
This indicates the approximate floor space occupied by lathe.

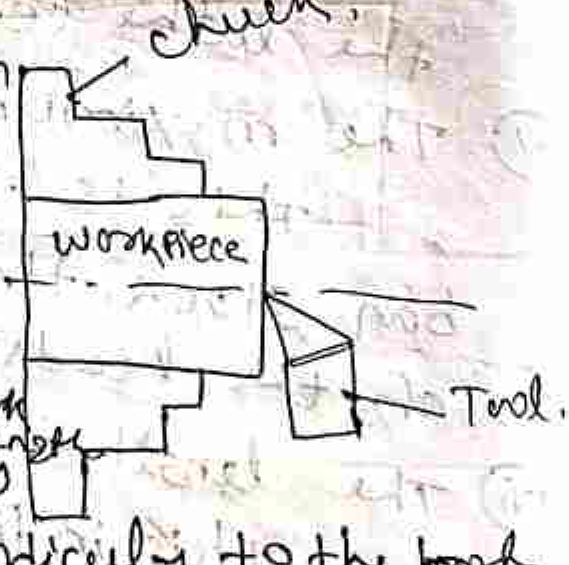
* LATHE Operation :

Common Lathe operations which can be carried out on a lathe are

1. (i) Facing.
2. (ii) Plain Turning
3. (iii) Step Turning.
4. (iv) Taper Turning.
5. (v) Threading.
6. (vi) Knurling
7. (vii) Reaming.
8. (viii) Boring.
9. (ix) Grooving or under cutting.
10. (x) Parting off
11. (xi) Drilling.
12. (xii) Forming.

(i) Facing :

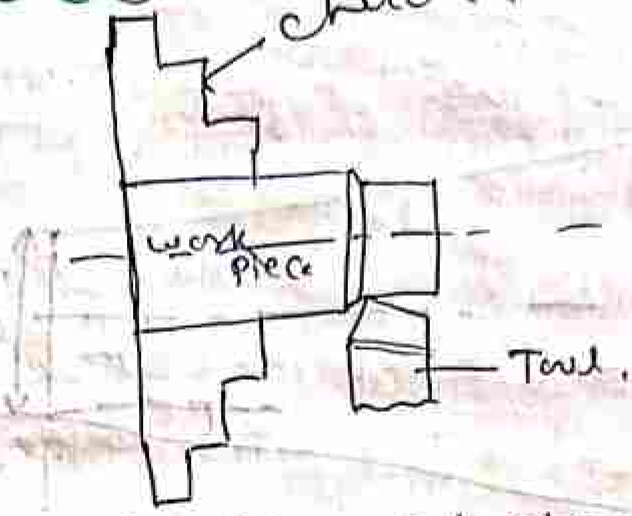
→ Facing is the operation of machining the ends of a piece of work to produce a flat surface square with the axis.



→ This is also used to cut the work to the reqd. length.

→ The operation involves feeding the tool perpendicular to the axis of rotation of the workpiece.

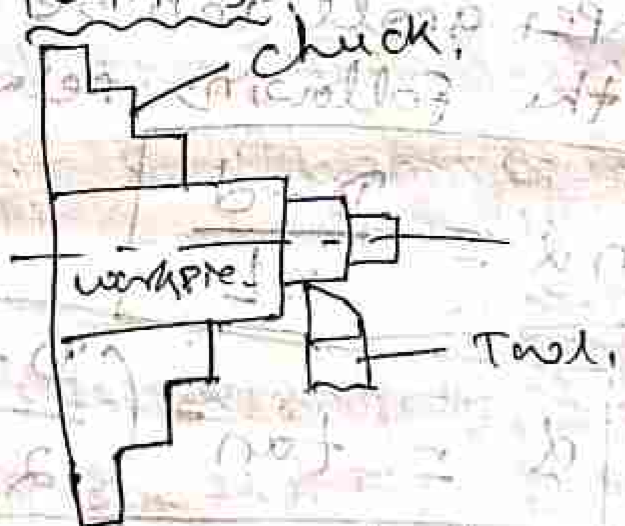
(ii) Plain Turning



→ The work is turned straight when it is made to rotate about the lathe axis, & the tool is fed parallel to the lathe axis.

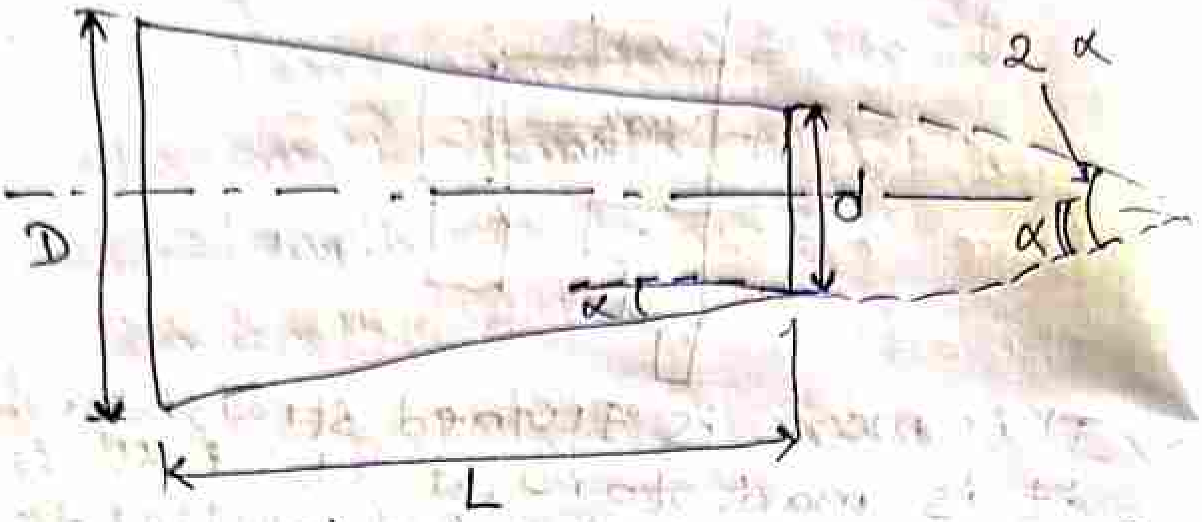
→ It is an operation of removing excess material from the (diameter) surface of the cylindrical workpiece.

(iii) Step Turning.



→ In this type of lathe operation, various steps of different diameters in the workpiece are produced.

(iv) Taper turning



→ A taper may be defined as a uniform increase or decrease in diameter of a piece of work measured along its length.

→ The taper angle can be found by using the following relationship.

$$\tan\alpha = \frac{D-d}{2L}$$

or

$$\alpha = \tan^{-1}\left(\frac{D-d}{2L}\right)$$

Where

D = Large diameter of taper in mm.

d = Small diameter of taper in mm.

α = angle of taper or half taper angle

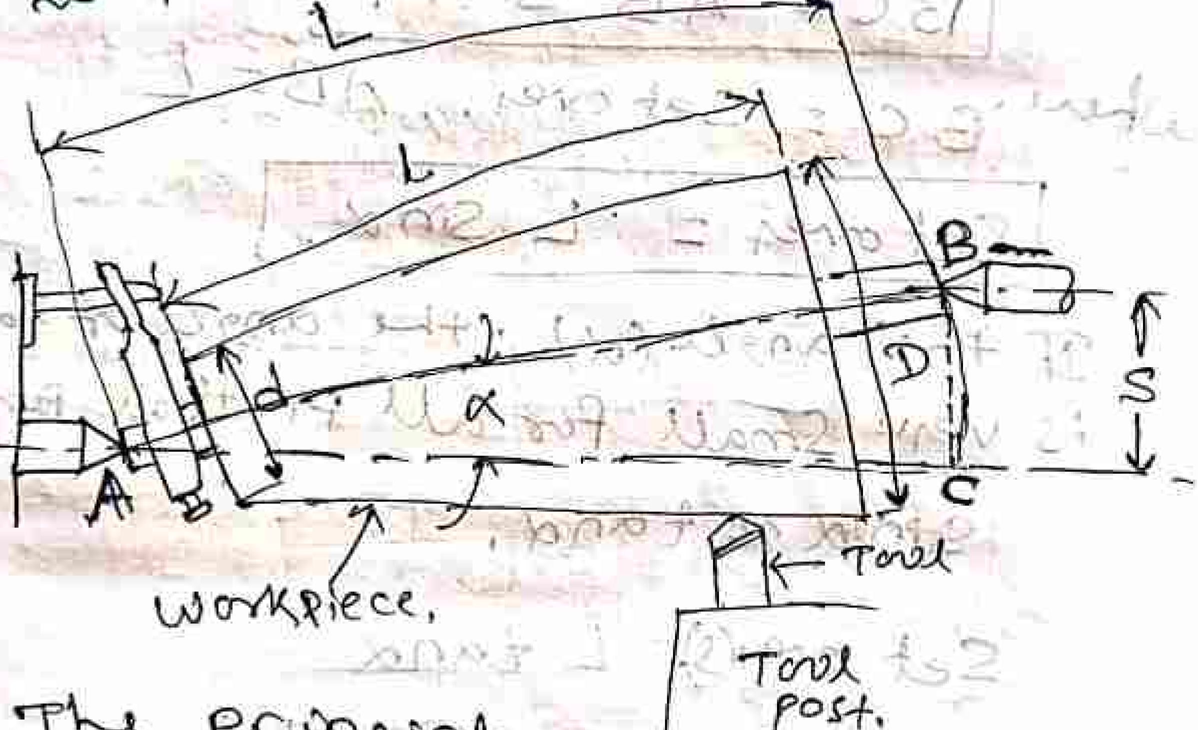
2α = Full taper angle.

* Methods of Taper turning :-

→ Various methods are used for taper turning. The most common of these are,

(a) By setting over the tailstock centre.
(b) By swivelling the compound rest.
(c) By using a broad nose from tool.
(d) By using the taper turning attachment.

(a) By setting over the tailstock



→ The principle of turning taper by this method is to shift the axis of rotation of the workpiece. is shifted equal to half angle of taper. This is done when the body of the tailstock is made to slide on its base towards or away from the operator by a set over screw.

→ The amount of setover being limited, this method is suitable for turning small taper on long job.

In this figure,

S = Setover in mm,

D = large diameter of taper,

d = small diameter of taper,

L = Length of the work

l = length of the taper.

From the right angle triangle ΔABC in F

$$BC = AB \sin\alpha.$$

where BC = Set over, AB = L

$$\text{Set over} = L \sin\alpha.$$

If the angle (α), the angle of taper, is very small for all pratical purposes

$\sin\alpha \approx \tan\alpha.$

$$\text{Set over}(S) = L \tan\alpha$$

$$\text{Setover}(S) = L\left(\frac{D-d}{2l}\right)$$

$$\text{Setover}(S) = \text{Total length}\left(\frac{\text{Total taper}}{2 \times \text{taper length}}\right)$$

Q3) Calculate the tailstock setover for turning a taper on a job such that its two diameters are 80 mm & 60 mm. Total length of the job is 300 mm. & the length of tapered of the portion is 200 mm only.

Given Data:

$D = 80\,mm$

$d = 60\,mm$

$L = 300\,mm$

$l = 200\,mm$

$$\text{Setover } (S) = L\left(\frac{D-d}{2l}\right)$$

$$= 300\left(\frac{80-60}{2\times 200}\right)$$

$$= \frac{300 \times 20}{2 \times 200}$$

$= 15\,mm$ (Ans)

b) By Swivelling the Compound rest.

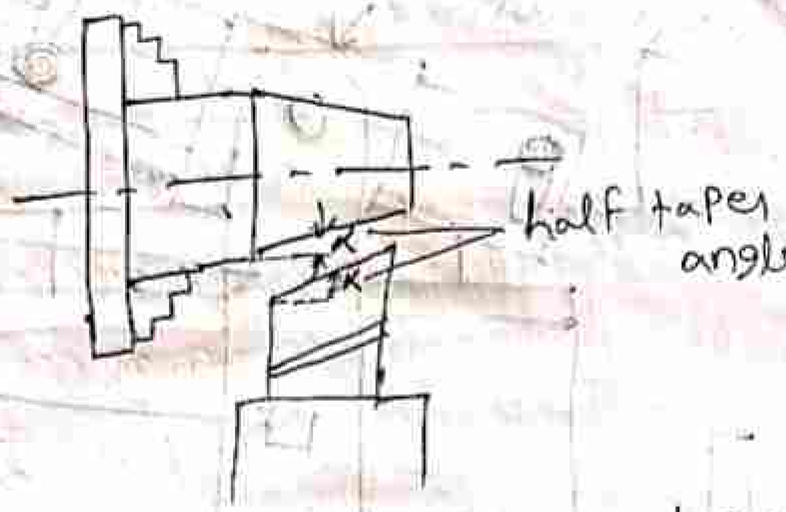
→ It is the method, it does not affect the centering of the job. In this method, the workpiece is rotated on the lathe axis & the tool is fed at an angle to the axis of rotation of the workpiece.

→ The tool mounted on the compound rest, the circular base, graduated in degrees, which may be swivelled & clamped at desired angle. The compound rest is set at the desired half taper angle.

→ The half taper angle can be calculated as,

$$\tan\alpha = \frac{D-d}{2L}$$

(4) By using a broad nose from tool



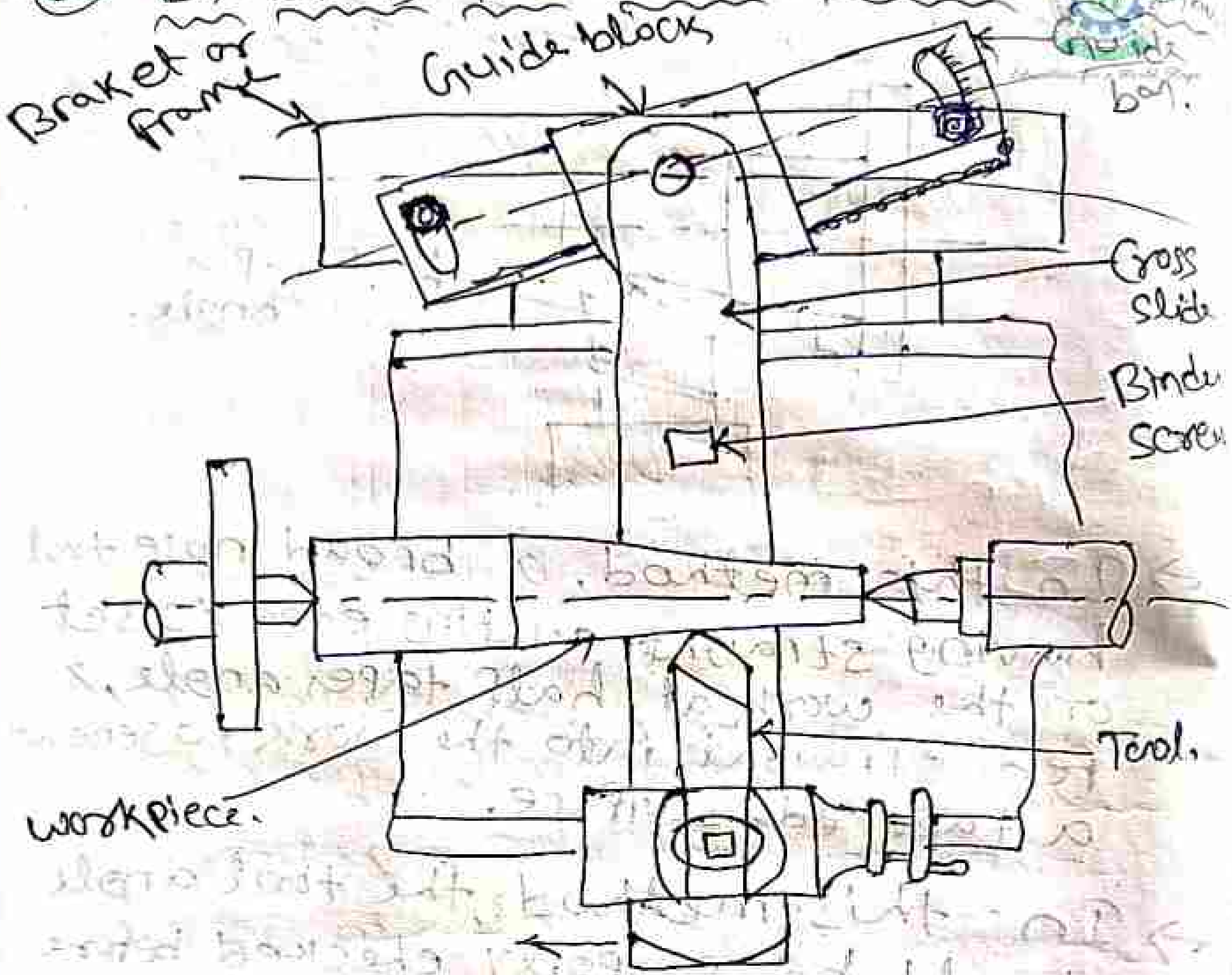
→ In this method, a broad nose tool having straight cutting edge is set on the work at half taper angle, & fed straight into the work to generate a tapered surface.

→ In this method the tool angle should be properly checked before use.

→ This method is limited to turn short length of taper only.

→ This will require excessive cutting pressure, which may distort the work due to vibration & spoil the work surface.

(d) By using the taper turning attachment



→ The principle of turning taper by a taper attachment is to guide the tool in a straight path set at an angle to the axis of rotation of the workpiece, while the work is being revolved between centres or by a chuck aligned to the lathe axis.

→ The taper turning attachment consists essentially of a braket or frame which is attached to the rear end of the lathe bed & supports a guide bar pivoted at the centre.

→ The bar having graduations in degree may be swivelled on either side of the zero graduation & is set at the desired angle with the lathe axis.

→ When the taper turning attachment is used, the cross slide is first made free from the lead screw by removing the binder screw. The rear end of the cross slide is then tightened with the guide block by means of a bolt.

→ When the longitudinal feed is engaged the tool mounted on the cross slide will follow the angular path, as the guide block will slide on the guide bar set at an angle to the lathe axis.

→ The required depth of cut is given by the compound slide which is placed at right angles to the lathe axis.

→ The guide bar must be set at half taper angle & the taper on the work must be converted in degrees. The maximum angle through which the guide bar may be swivelled is 10° to 12° on either side of the centre line.

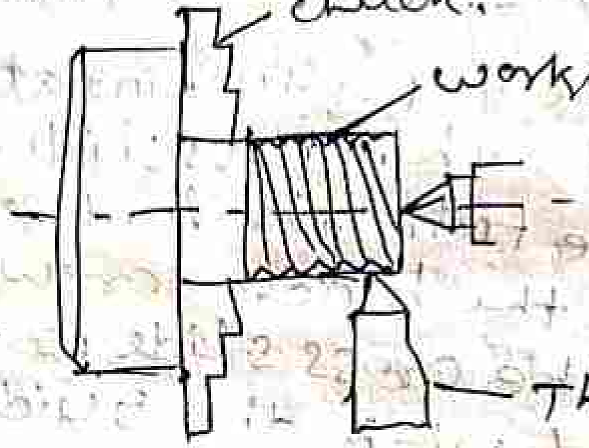
→ The Angle of swivelling the guide bar can be determined from equation.

$$\tan \alpha = \frac{D-d}{2L}$$

(V) Threading :

* External thread

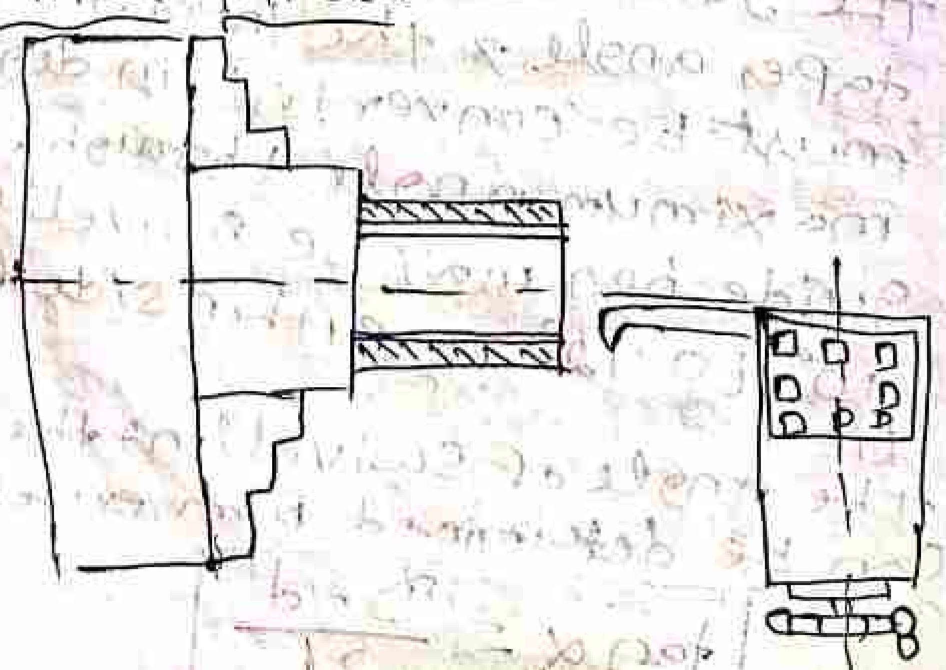
→ Threading is an operation of cutting helical grooves on the external cylindrical surface of the workpiece.



→ In this operation the workpiece is held in a chuck or between centres & the threading tool is fed longitudinally to the revolving work. The

longitudinal feed = the pitch of the thread to be cut

* Internal thread



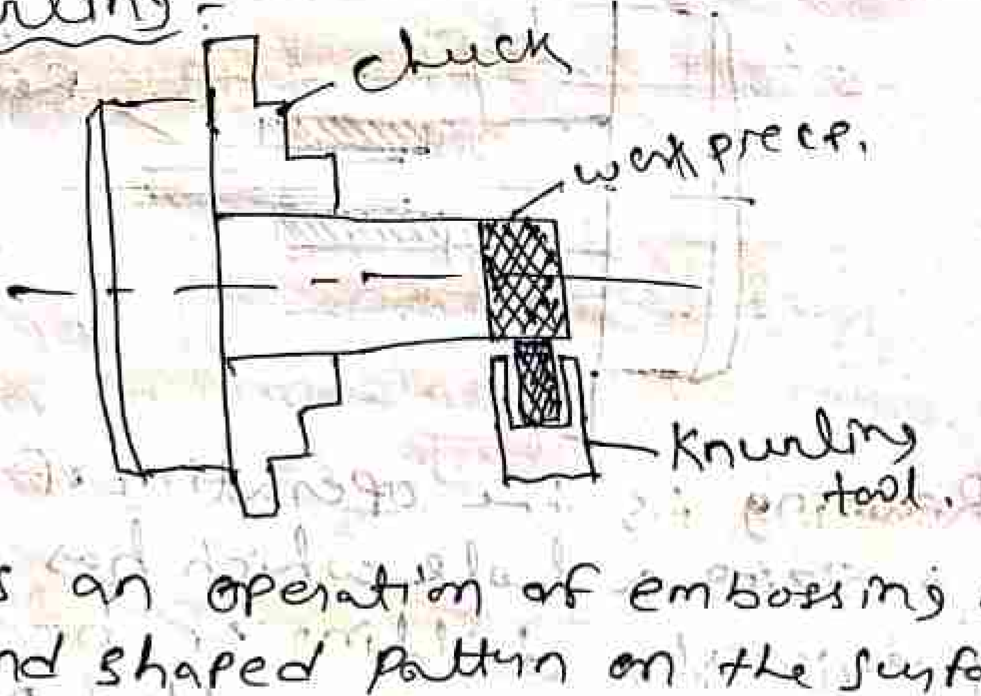
→ It is similar to that of an external thread, the only difference being in the tool used.

→ The tool is similar to a boring tool with cutting edges ground to the shape conforming to the type of the thread to be cut.

→ The hole is first bored to the root diameter of the thread.

→ For cutting metric thread, the compound slide is swiveled 30° toward the headstock. The tool is fixed on the tool post or on the boring bar after setting it at right angles to the lathe axis.

(vi) Knurling :-



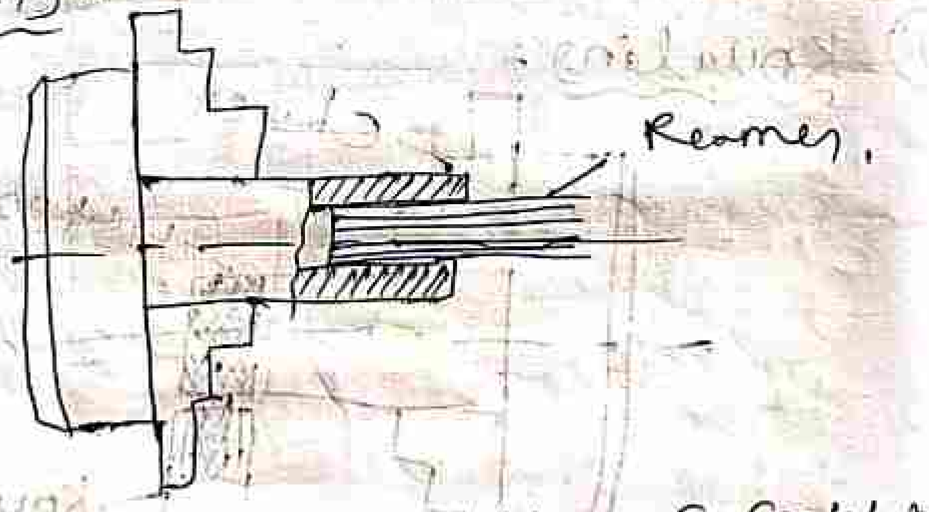
→ It is an operation of embossing a diamond shaped pattern on the surface of a workpiece.

→ The purpose of knurling is to provide an effective gripping surface on a workpiece to prevent it from slipping when operated by hand.

→ The operation is perfo... special kind knurling tool which consists of 1 set of hardened steel rollers in a holder with the teeth cut on their surface in a definite pattern. The tool is held rigidly on the tool post & the rollers are pressed against the revolving workpiece to squeeze the metal against the multiple cutting edges, producing depres in a regular pattern on the surface of the workpiece.

→ This operation performed at the slowest speed.

(vii) Reaming :-



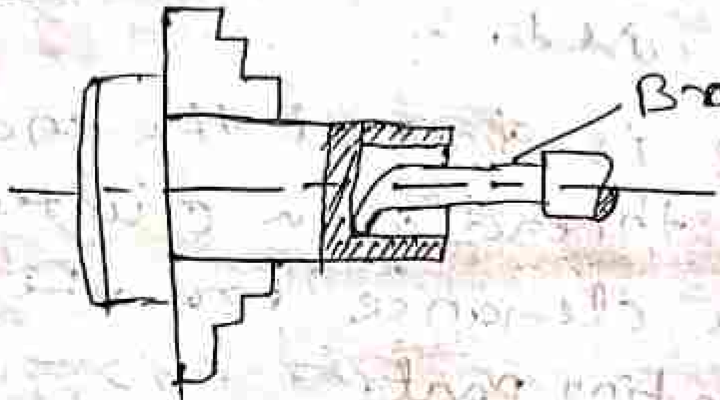
→ Reaming is the operation of finishing & sizing a hole which has been previously drilling or bored.

→ The tool used is called reamer, which has multiple cutting edges.

→ The reamer is held on the tailstoc spindle, either direct or through a drill chuck & is held stationary while work piece is revolved at a very low speed.

→ The feed varies from 0.5 to 2 mm per revolution.

(viii) Boring :-



→ It is the operation of enlarging a previsously made hole produced by drilling, punching, casting or forging. Boring cannot originate a hole.

→ It is similar to the external turning operation & can be performed in a lathe.

→ In this operation, a boring tool or a bit mounted on a rigid bar is held in the tool post & fed into the work by hand or power.

(ix) Grooving :- It is the process of reducing the dia. of a workpiece over a very narrow surface. It is often done at the end of a thread or adjecent to a shoulder to leave a small margin. The work is revolved half speed of turning & a grooving tool of reqd. shape fed straight into the work by rotating the cross slide screw. It is similar to parting off tool.

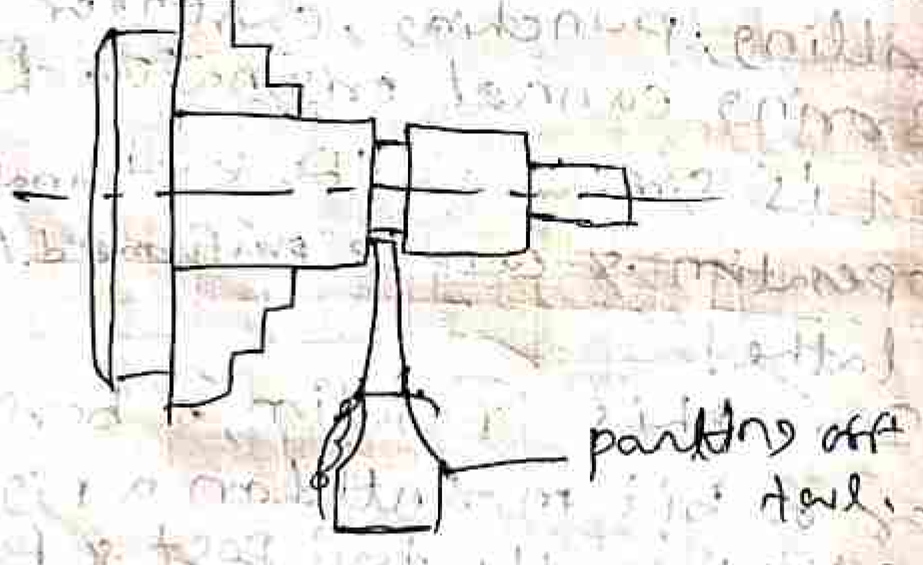
(ix) Grooving or under cutting :-

→ It is the process of boring a groove or a large hole at a fixed distance from the end of a hole, this is similar to boring operation.

→ expect that a square nose parting tool is used.

→ Grooving is done at the end of an internal thread or a counter bore to provide clearance for the tool or any mating part.

(X) parting off



→ Parting off is the operation of cutting a workpiece after is has been machined to the desired size & shape.

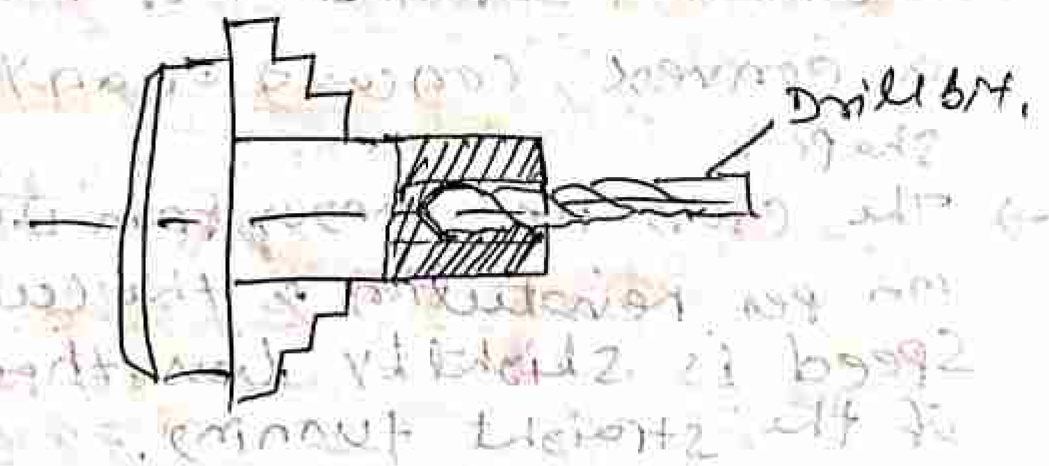
→ This process involves rotating the workpiece on a chuck or faceplate at half the speed that of turning & feeding by a narrow parting off tool perpendicular to the lathe axis. by rotating the cross-slide screw by hand.

→ Before the operation is started, the carriage is locked in position of lathe bed & the cutting tool is held rigidly on the tool post with the compound slide set parallel to the lathe axis.

→ The tool should be fed very slowly to prevent chatter. The feed varies from 0.07 to 0.15 mm per revolution. & depth of cut ~~speed~~ which is equal to the width of the tool ranges from 3 to 10 mm.

→ The parting tool is first fed through a certain depth it is then withdrawn & two or more cuts are made at the two sides of the central groove. The tool is next fed into the central groove until the work is cut off in two parts.

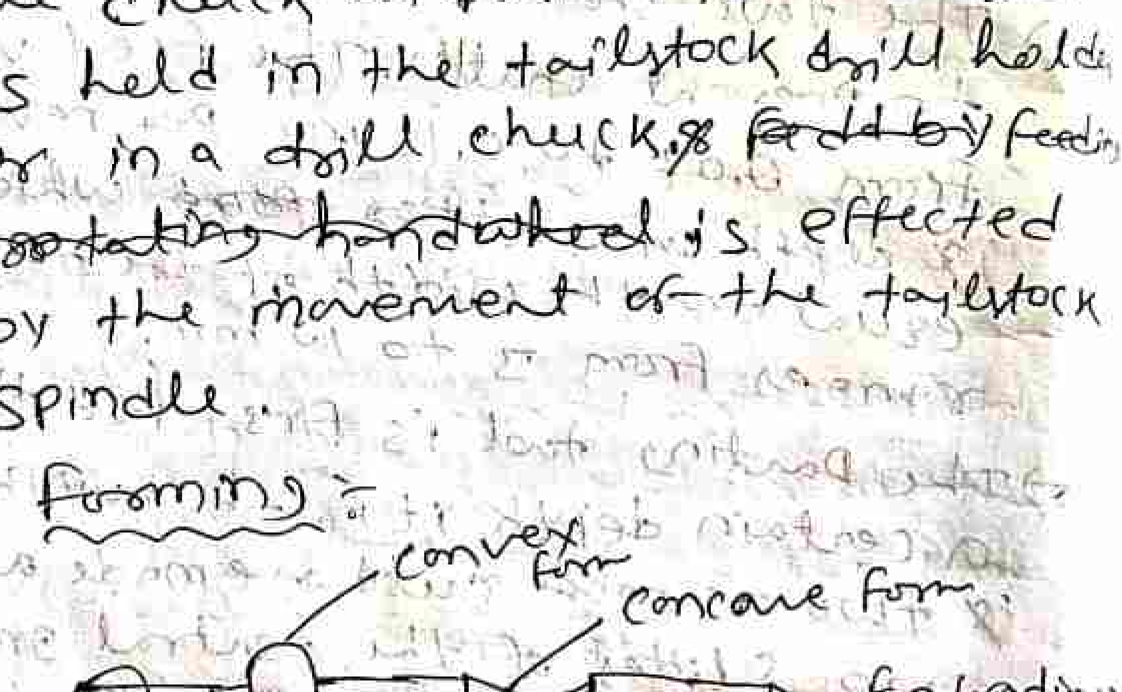
(Xi) Drilling :-



→ It is an operation of producing a cylinderical hole in a workpiece either by rotating the workpiece or cutting edge of a cutter known as the drill.

→ In this case workpiece is clamed on the chuck ~~on faceplate~~ & the drill is held in the tailstock drill holder or in a drill chuck & ~~feed by~~ feeding ~~rotating handwheel~~ is effected by the movement of the tailstock spindle.

(xii) Forming :-



→ It is an operation of turning a convex, concave or any irregular shape.

→ The cross feed ranges from 0.01 to 0.08 mm per revolution & the cutting speed is slightly less than that of the straight turning.

* Cutting Speed, Feed, Depth of cut :-

(i) Cutting Speed :-

→ The cutting speed is the peripheral speed of the workpiece over the cutting tool.

→ Distance travelled per minute in a direction parallel to the direction of feed.

Mathematically $$V = \frac{\pi D N}{1000} \text{ m/min.}$$

V = cutting speed (m/min).

D = Diameter of the job (mm)

N = Speed of work in (R.P.M)

(ii) Feed :-

→ Feed may be defined as the distance that a tool advances into the work during one revolution.

* The smaller the feed, the better the finish although a great deal depends on the type of lathe tool used, & a well sharpened tool is necessary.
* Larger feeds reduce machining time, but the tool life is reduced.

$$f = \frac{L}{N \times T_m}$$ mm/revolution

where
L = Length of cut (mm)
N = spindle speed, (rpm)
f = feed (mm/revolution)
T_m = machining/cutting time, (min)

(iii) Depth of cut

→ Thickness of metal removed in a cut by the tool is known as depth of cut.

→ It can be defined as the distance measured normal to the work axis by which the point of the tool penetrates into the job surface in a cut.

It can be expressed.

$$d = \frac{D_i - D_f}{2}$$ mm

where d = depth of cut (mm)
D_i = Initial/original diameter of the workpiece (mm)
D_f = final diameter of the workpiece (mm)

* Material removal rate (MRR)

→ The material removal rate is the volume of material removed per unit time.

It can be expressed

$$MRR = \pi D_i \times d \times f \times N \quad mm^3/min$$

D_i → Initial diameter (mm)

d → depth of cut (mm)

f → feed (mm/revolution)

N → spindle speed (rpm)

→ In term of cutting speed (V) m/min is given by.

$$MRR = 1000 \times V \times d \times f \quad mm^3/min.$$

Q) Explain with the help of a neat sketch, the principle of working in a Lathe?

Q) What is lathe carriage? Explain its various parts with the help of sketch?

Q6) A 160mm long 15 mm diameter rod is reduced to 14 mm diameter in a single pass straight turning. If the spindle speed is 450 rpm & feed rate is 225 mm/min determine
(i) Material removal rate (MRR)
(ii) cutting time (T_m)

Sol: $L = 160\,mm$, $D_i = 15\,mm$, $D_F = 14\,mm$

$N = 450\,rpm$, $f = 225\,mm/min$

$= 225/450$

$= 0.5\,mm/rev.$

$MRR = \pi D_i \times d \times f \times N$

$d = \frac{D_i - D_F}{2} = \frac{15-14}{2} = 0.5\,mm$

(i) $MRR = (\pi \times 15) \times 0.5 \times 0.5 \times 450$

$= 5301.43\,mm^3/min$ (Ans)

(ii) $T_m = \frac{L}{f \times N} = \frac{160}{0.5 \times 450}$

$= 0.711\,mm$ (Ans)

(ii) Speed Lathe:-

→ In this lathe spindle can rotate at very high speed with the help of a variable speed motor built inside the headstock of the lathe.

→ It is used mainly for wood working, Metal spinning, polishing etc.

(A) Spinning:-

→ It is also known as spin forming. It is metal working process by which a disc or tube of metal is rotated at high speed & formed into an axially symmetric part.

→ It does not involve remove of material, as in conventional wooden metal turning, but forming (moulding) of sheet material over an existing shape.

(iii) Bench lathe:-

→ It is usually mounted on a bench.

→ It is very similar to speed or centre lathe, the only difference being it is smaller in size which enables it handle small & precision work.

(IV) Tool room lathe :-

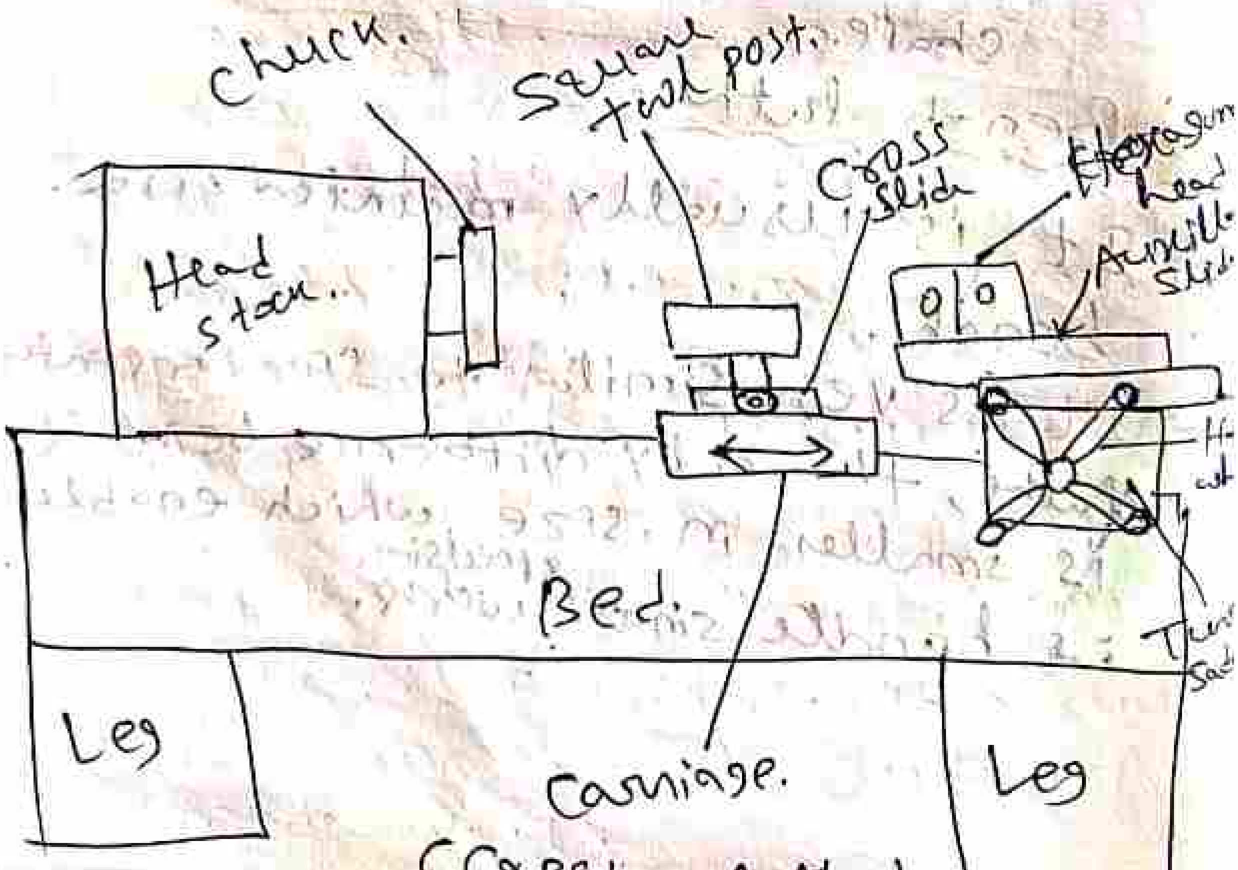
→ It is similar to engine lathe, designed for obtaining accuracy.

→ It is used for manufacturing precision components, dies, tools, jigs etc.

(V) Turret & Capstan Lathe

→ These lathe have provision to hold a number of tools can be used for performing wider range of operation.

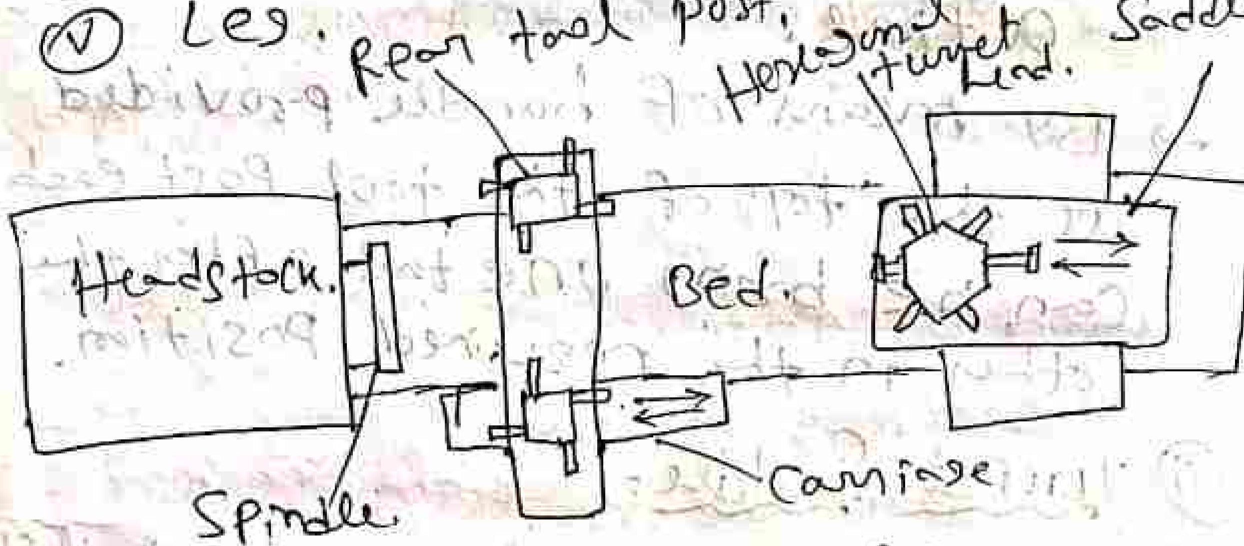
→ These are particularly suitable for mass production of identical parts in minimum time.



(Capstan Lathe)

* The main parts are.

(i) Head stock.
(ii) carriage or chaser saddle.
(iii) Turret saddle.
(iv) Bed.
(v) Leg.



(Turrent lathe (Top view).

(i) Head stock: A Turret or capstan lathe carries a similar type of head stock as a center lathe, but is comparatively larger size & heavier in construction

(ii) Carriage or chaser saddle:
⇒ It is mounted on the bed of a turret or capstan lathe. It is not much different from center lathe. It caries cross slide over it, on which two tool post are mounted.

→ one at the front & other at the rear. It does not carry a Compound rest. Both tool post are Square ~~tool~~ size, in which each is capable of holding 4 tools at a time.

→ By means of handle provided at the top of the tool Post, each can be bring one tool after the other in the required position.

(iii) Turret Saddle:-

→ This saddle replaces the tail stock of a centre lathe. It mounted directly on the lathe bed on the Same Side as a tail stock in the center lathe. It can be two types.

(a) Turret lathe :- In this type of lathe which travels longitudinally along with the tool & the turret head carrying the tool is mounted directly on it.

(b) Capston lathe :- In this type of lathe, is provided with a slide which moves in the guide ways made in it.

* In this type the turret head is mounted on the slide. During operation saddle remains stationary & the tools are fed longitudinally by moving the ~~slide~~ Auxillary slide.

→ The turret head is usually hexagonal in turret lathe & circular or hexagonal in capstan lathe.

→ ~~Circ~~ Circular turret is having six holes, one each on each flat face, or equiplaced along the periphery on the circular head.

→ In case of hexagonal turret one face carries four threaded holes.

(IV) Bed :- It is box type casting. It supports the other part over it.

(V) Legs :- Each lathe carries two legs, one below each end of the bed, which bear the entire load of the bed.

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→ Difference between the turret Capstan Lathe.

Turret lathe	Capstan lathe
① Its turret head is mounted directly on the saddle.	① Its turret head is mounted on an auxill. slide.
② For feeding the tool to the workpiece, the entire saddle unit is moved.	② Saddle is fixed, the tool are fed by moving the slide.
③ It can move almost full length of the bed along with tool if needed.	③ Tool travel is limite. as the feeding is done by slide.
④ It is capable of carrying heavier job.	④ Relatively lighter & smaller job.
⑤ Tool travel relatively slower.	⑤ Tool feed is faster.
⑥ The turret head is hexagonal.	⑥ The turret head is circular or hexagonal.

(vi) Automatic lathe :-

→ These lathes are so designed that the tools are automatically fed to the work & withdrawn after all operations to finish the work, are complete.

→ They require little attention of the operator, since the entire operation is automatic.

→ These are used for mass production of identical parts. (* to be cont. next page)

(vii) Special purpose lathe.

→ These are used for special purpose & for jobs which cannot be accommodated or conveniently machined on a standard lathe. The lathes included in this category.

(a) Wheel lathe :- These lathes are designed for finishing & turning the thread on rail road car & locomotive wheels.

(b) Gap bed lathe :- It is used for machining extra large diameter pieces.

* How automation affects the P[illegible]

→ Two types of operations are requir[illegible] in metal machining.

(i) The actual removal of metal by means of different cutting tools.

(ii) Handling, this includes loading, unloading, mounting & removal of cutting tool. feeding tools & inspection of work during machining

→ The total time taken in Production is sum of separate timing of all above. Therefore that quicker the above operation are performed less will be the time taken in producing the component that means the same machine will be able to produce more number of component in same time.

→ And also the operator will be free to utilise his time elsewhere during the operation of this machine with the result, the operator will be able to handle more machine at the same time.

→ Both the above factors will ultimately result in an increased rate of production.

* DRILLING * Machine *

→ Drilling is an operation through which holes are produced in a solid metal by means of a revolving tool called Drill. Since it is not possible to produce a perfectly true holes by drilling.

→ It is considered as a roughing operation for such holes, drilling is followed by another operation called reaming, in which required dimensional accuracy & fine surface finish are obtained by means of a multitooth revolving tool called reamer. Boring is the operation employed for enlarging an existing hole.

→ The tool used for drilling is called a Drill bit.

~~* Classification of Drills:~~

→ In drilling the tool called drill is rotated & pressed against the stationary work. However if drilling is done on a lathe, then work is rotated & the drill remain stationary. Fundamentally a drilling machine processes, a spindle for giving rotational movement to drill some device (manual or Automatic) for feeding the drill, & a work holding arrangement.

* Classification of drilling machine

→ Drilling machines are made in many different types & sizes, each designed to handle a class of work or specific job to the best advantage.

The different types of drilling machines are:

1. Portable drilling machine.
2. Sensitive drilling machine.
   - (a) Bench mounting.
   - (b) Floor mounting.
3. Upright drilling machine / Pillar drilling machine
   - (a) Round column section.
   - (b) Box column section.
4. Radial drilling machine.
   - (a) Plain (b) Semiuniversal (c) Universal
5. Gang drilling machine.
6. Multiple spindle drilling machine.
7. Automatic drilling machine.
8. Deep hole drilling machine.

① portable drilling machine.:-

→ The common of this type is the hand drill. It has no table for fixing workpiece & no base to stand on the workpiece is held on some bench table or vice the drilling machine in hand for drilling operation.

→ It is equipped with a small electric motor & its switches.

→ These drill operate at fairly high speed and accomodate drills upto 1/2 inch in diameter. The feeding of the drill is provided manually & in fact the whole drilling machine moves at the time of feed.

② Sensitive drilling machine.

→ It is a small, light, high speed machine used primarily for drilling small parts.

→ Such machines have usually hand feeding arrangement which is done with the help of rack (linear gear) & pinion (circular gear) combination.

→ The drills may be driven directly with a belt, ~~a motor with the help~~ a motor or by means of a friction disc, The friction disc drive give very high speed.

→ The typical range of speed such machine is 800 to 4000 rpm. Since horse power is small.

→ As the operator senses the cutting action, at any instant, so it is called Sensitive drilling machine. This machine are capable of rotating drills of diameter from 1.5 to 15.5 mm.

③ Upright drilling machine / Pillar drilling machine

→ This is designed for handling medium sized workpieces. This machine is very similar to a sensitive drilling machine for having vertical column mounted upon the base.

→ This machine consists of a round column that rises from the base which rests on the Floor, an arm & a round table assembly, & a drill head assembly.

→ The arm & the table have three adjustments for locating workpiece under the spindle. The arm & the table may be moved up & down & the arm may be moved in an arc upto 180° around the column & may be clamped at any position.

→ Table may be rotated 360° about its own center independent of the position of the arm for the locating workpieces under the spindle.

→ Construction of the machine being not very rigid & table supported on a horizontal arm, intened for lighter work & maximum size of holes that the machine can drill is not more than 50mm.

(4) Radial drilling machine:-

→ The radial drilling machine is intended for drilling medium to large & heavy workpiece. The machine consists of a heavy, round, vertical column mounted on a large base.

→ The column supported a radial arm which can be raised & lowered accomodate workpiece of different heights.

→ The arm may be swung around to any position over the work bed.

→ The drill head containing mechanism for rotating & feeding the drill is mounted on a raial arm & can be moved horizontally on the guide ways & clamped at any desired position.

→ These three movement in a radial drilling machine when combined together permit the drill to be located at any desired point on a large workpiece for drilling the hole.

(5) Gang drilling machine

→ When a number of single spindle drilling machine columns are placed side by side on a common base & have a common worktable, the machine is known as the Gang drilling machine.

→ In this machine 4 to six spindles may be mounted side by side.

→ In some machines the drill spindles are permanently spaced on the work table, & in other the position of the columns may be adjusted so that the space between the spindles may be varied.

→ The speed & feed of the spindles are controlled independently. This type of machine is specially adapted for production work.

→ A series of operation may be performed on the work by simply shifting the work from one position to the other on the work table.

→ Each spindle may be set up properly with different tools for different operations.

(b) Multiple spindle drilling machine

→ The function of a multiple spindle drilling machine is to drill a number of holes in a piece of work simultaneously & to reproduce the same pattern of holes in a number of identical pieces in a mass production work.

→ Such machines have several spindle driven by a single motor & all the spindle holding drills are fed into the work simultaneously.

→ Feeding motion is usually obtained by raising the work table, but the feeding motion may also be secured by lowering the drill heads.

→ The spindles are so constructed that their centre distance may be adjusted in any position as required by various jobs with in the capacity of the drill heads. For this purpose, the drill spindle are connected to the main drive by universal joints.

⑦ Automatic drilling machine :

→ It can perform a series of machining operations at successive units & transfer the work from one unit to the other automatically.

→ Once the work is loaded at the first machine, the work will move from one machine to the other where different operations can be performed & the finished work comes out from the last unit without any manual handling.

→ This type of machine is intended purely for production purpose.

⑧ Deep hole Drilling machine

→ Special machines & drill are required for drilling deep holes in rifle barrels, crankshaft, long shafts etc.

→ The machine is operated high speed & low feed.

→ Sufficient quantity of lubricant is pumped to the cutting points for removal of chips & cooling the cutting edges of the drill.

→ A long job is usually rotated while the drill is fed into the work

→ A long job is usually supported at several points to prevent any deflection.

→ The work is usually rotated while the drill is fed into the work. This helps in feeding the drill in a straight path. In some machines both the work & the drill are rotated for accurate location. The machine may be horizontal or vertical type. In some machines step feed is applied.

→ The drill is withdrawn automatically each time when it penetrates into the work to a depth equal to its diameter, to permits the chip to clear out from the work.

Operation on drilling machine

The following are the operations that can be performed on a drilling machine.

1. Drilling.
2. Reaming
3. Boring.
4. Counter boring.
5. Counter sinking.
6. Spot facing
7. Tapping.
8. Lapping.
9. Trepanning.

① Drilling :-

→ It is the operation of producing a cylindrical hole be removing metal by the rotating edge of a cutting tool called drill.

→ Before drilling the center of the hole is located on the workpiece by drawing two line at right angles to each other & then a center punch is used to produce an indication at the center.

→ The drill point is pressed at this center point to produce the required hole.

→ Drilling does not produce an accurate hole in a workpiece & the hole so generated by drilling becomes rough & the hole is always slightly oversize than the drill used due to the vibration of the spindle & drill.

② Reaming :-

→ It is an accurate way of sizing & finishing a hole which has been previously drilled.

→ In order to finish a hole & to bring it to the accurate size, the hole is slightly under size.

→ The tool used for reaming is known as the reamer which has multiple cutting edges.

→ Reamer cannot originate a hole. It simply follows the path which has been previously drilled & removes a very small amount of metal.

(3) Boring:-

→ To enlarge a hole by means of an adjustable cutting tool with only one cutting edge. This is necessary where suitable sized drill is not available or where hole diameter is so large that it cannot be ordinarily drilled.

→ The cutter is held in a boring bar which has a taper shank to fit into the spindle socket.

(4) Counter boring:-

→ It is a cylindrical flat bottomed hole that enlarges another co-axial hole, or the tool used to create that feature.

→ This is necessary in some cases to accomodate the heads of bolts, studs & pins. The tool used for counter boring is called counter bore.

→ The counter bores are made with straight or tapered shank to fit in the drill spindle.

→ The cutting edges may have straight or spiral teeth.

→ The tool is guided by a pilot which extends beyond the end of the cutting edge.

→ The pilot fits into the small diam hole having running clearance & maintains the alignment of the tool.

→ The pilot may be interchanged for enlarging different size of holes.

→ Cutting speed for counter boring is 25% less than that of drilling opsn.

⑤ Counter Sinking :-

→ It is the operation of making a cone shaped enlargement of the end of hole to provide a recess for a flat head screw or countersunk rivet fitted into the hole.

→ The tool used for counter sinking is called countersink.

→ Standard countersink have 60°, 82° or 90° include angle & the cutting edge of the tool are formed at the conical surface.

→ The cutting speed in countersinking is 25% less than that drill.

⑥ Spot facing :-

→ It is a finishing operation to produce flat round surface usually around a drilled hole, for proper seating of bolt head or nut.

→ A counter bore or a special spot facing tool may be employed for this purpose.

⑦ Tapping:

→ Process of cutting internal threads with a thread tool called as tap.

→ Tap is a fluted threaded tool used for cutting internal thread.

→ The threads act as cutting edges which are hardened & ground.

→ cutting speed is very slow. when the tap is screwed into the hole it removes metal & cuts internal threads which fit into external threads of the same size

Classification of drills:-

① According to the type of shank
(i) parallel or straight shank (Drill upto 12 mm) (ii) Taper Shank (larger size.)

② According to the type of flutes
(i) Flat drill (parallel longitudinal feed)
(ii) Twist drill (Spiral / helical flute)

③ According to the length.
(i) Short length drill
(ii) stub length drill
(iii) long length drill.

④ According to the tool material.
(i) High speed steel drills.
(ii) Carbide tipped drills.

⑤ According to the applications.

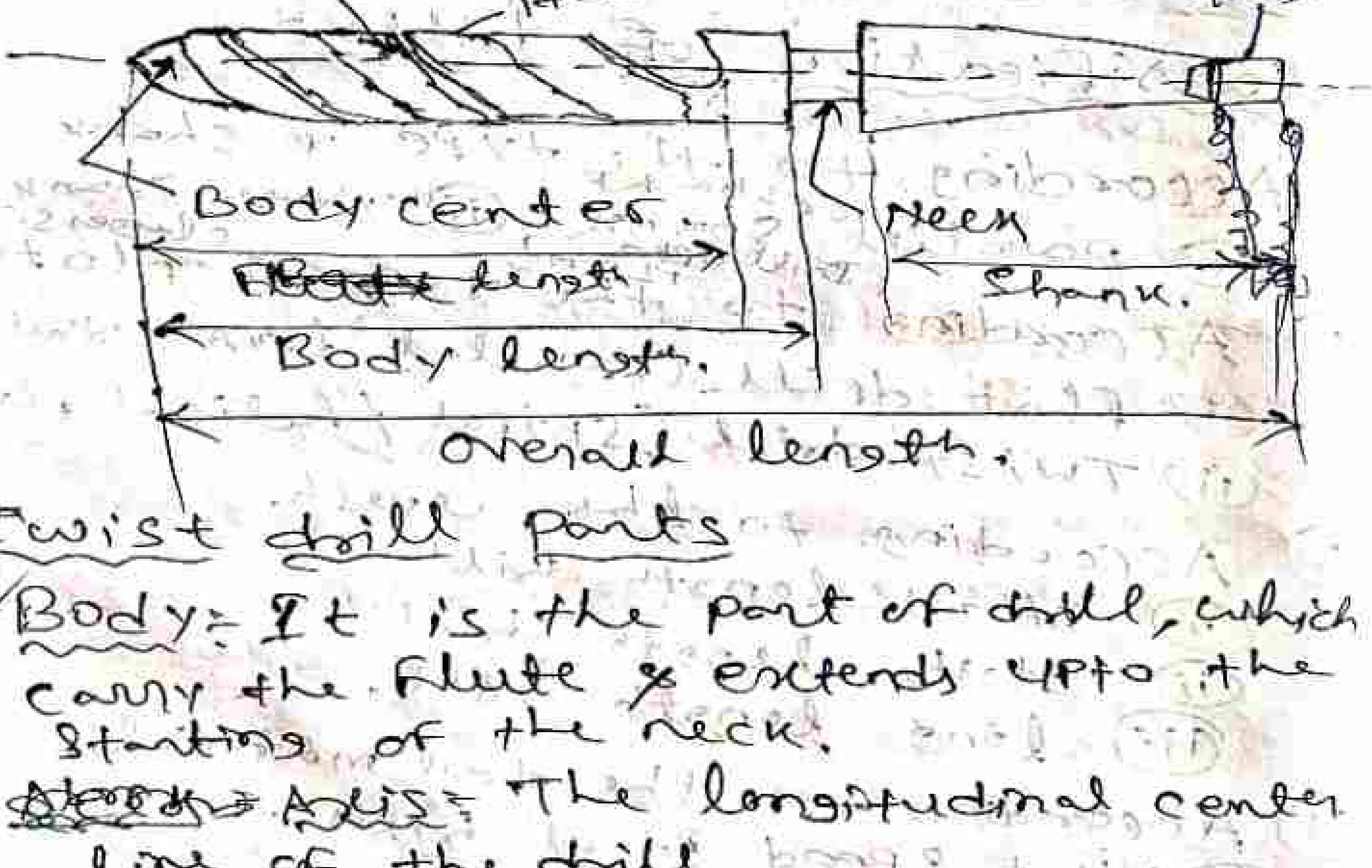
(i) Core drills.

(ii) Drills for long hole drilling.

(iii) Center drills.

* Twist Drill Nomenclature:-

→ Twist drill is the most widely used tool. It consists of a cylindrical body, carrying two spiral flutes cut on it. Twist drill are made up of High speed steel.

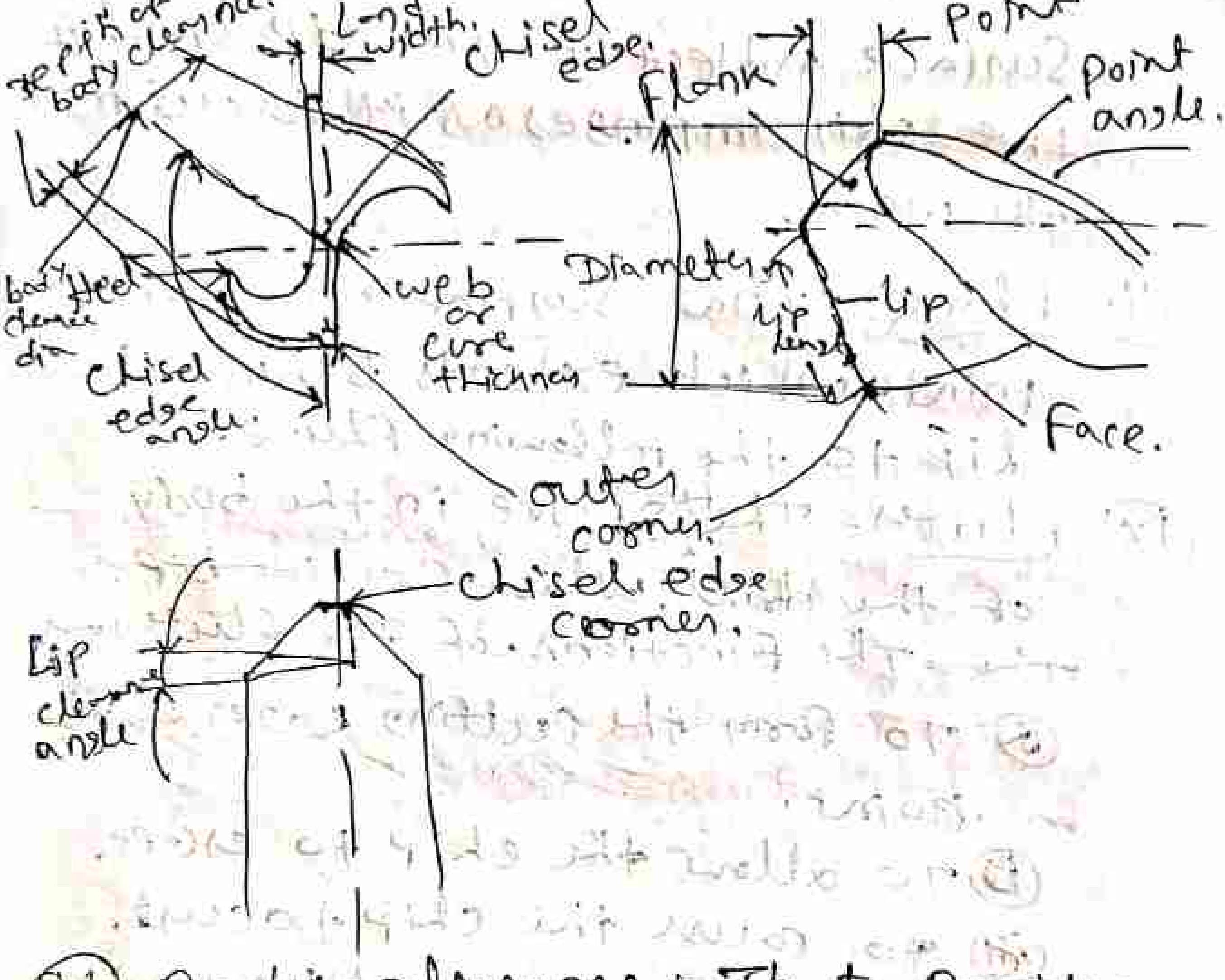


Twist drill parts

(i) Body:- It is the part of drill, which carry the flute & extends upto the starting of the neck.

(ii) ~~Nessy~~ Axis:- The longitudinal center line of the drill.

(iii) Shank :- The Portion of the drill beyond the neck, which is gripped in the holding device. It may be Parallel or tapered.



(iv) Body clearance :- That portion of body surface which is reduced in diameter to provide diameter clearance.

(v) Chisel edge :- The edge formed by intersection of the flanks. The chisel edge is also sometimes called dead centre. The chisel edge is also acts as a flat drill & cuts its own in the workpiece.

(vi) Chisel edge corner :-
The corner formed by the intersection of a lip & the chisel edge.

(vii) Face :- The portion of the flute surface adject to the lip on which the chip impinges as it is cut from the work.

(viii) Flank :- That surface on a drill point which extends behind the lip to the following flute.

(ix) Flutes :- The helical groove in the body of the drill. ~~which provide lip~~.
~~the~~ The functions of the flutes are
(a) To form the cutting edges on the point.
(b) To allow the chip to escape.
(c) To cause the chip to curl.
(d) To permit the cutting fluid to reach the cutting edges.

(x) Heel :- The edge formed by the intersection of the flute surface & the body clearance.

(xi) Land :- The cylindrical ground surface on the leading edges of the drill flutes. Land keeps the drill aligned.

(xii) Lip (cutting edge) :- The edge formed by the intersections of the flank & face. The requirements of the drill lips are.

(a) Both lips should be at the same angle of inclination with the drill axis, 59° for general work.

(b) Both lips should be of equal length.

(c) Both lips should be provided with the correct clearance.

(xiii) Neck :- The smaller diameter. cylindrical portion which seperates the body & shank of a drill.

(xiv) outer corner :- The corner formed by the intersection of the flank & face.

(xv) Point :- The cone shaped surface at the end of the flutes & containing the dead center, is is called point. (118°)

(xvi) Tang :- The flattened end of the taper shank intended to fit into a drift slot in the spindle, socket or drill holder.

(xvii) web :- The central portion of the drill situated between the roots of the flutes & extending from the point toward the shank, the point end of the web or core form the chisel edge.

Drill material :-

The materials for the manufacture of twist drills as follows.

① one piece construction:

High speed steel or carbon steel

② Two piece construction :-

cutting portion - High speed steel

shank portion → carbon steel,

→ High speed drills are more widely used due to its greater cutting efficiency. Cemented carbide tipped drills are also used in mass production work.

Cutting speed (V) :-

$$V = \frac{\pi D N}{1000} \quad m/min.$$

where D → diameter of drill (mm)

N → spindle speed rpm

* Feed (F)

It is a distance, a drill moves parallel to its axis into the work in each revolution of the spindle. It is expressed in mm/rev.

$$\text{Feed in mm/min} = \text{feed mm/rev} \times N$$

* Depth of cut.

$$d = \frac{D}{2} \text{ mm.}$$

$d \rightarrow$ depth of cut.

$D \rightarrow$ Diameter of the drill.

* Machining time in drilling.

$$T = \frac{L}{N \times F} \text{ min.}$$

L = length of travel of the drill (mm)

$N \rightarrow$ spindle speed.

$F \rightarrow$ feed (mm/rev)

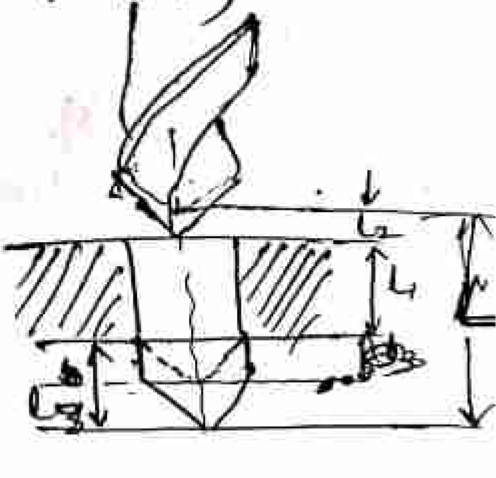
$T \rightarrow$ machining time (min)

$L = L_1 + L_2 + L_3$

L_1 = length of the workpiece.

L_2 = approach of the drill (0.29d) (with point angle 118°)

L_3 = Tool over travel (1 to 2mm)



* Material removal rate (MRR)

$$MRR = \frac{\pi D^2 F N}{4} \quad mm^3/min$$

Area of cross section of the hole × the tool traverses through

D → Diameter of drill

F → feed (mm/rev)

N → Spindle speed (rpm)

Q) A hole of 20 mm dia is to be drilled through a mild steel plate 16 mm thick. Calculate the rpm of the drill spindle when cutting speed is 26 m/min.

D = 20 mm, t = 16 mm.

$V_c = 26 \ m/min$

$$V_c = \frac{\pi D N}{1000}$$

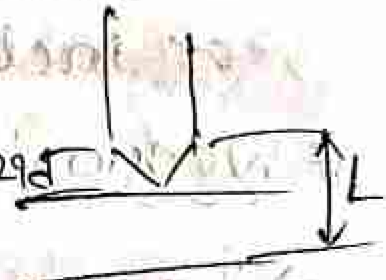
$$N = \frac{V \times 1000}{\pi \times D} = \frac{26 \times 1000}{\pi \times 20}$$

$= 414$ rpm (Ans)

Q) Calculate the machining time for drilling 4 holes of 16 mm dia each on a flange from the following data. Flange thickness 30 mm, cutting speed 22 m/min, feed 0.2 mm/rev.

No. of holes = 4

D = 16 mm.



t = 30 mm, V_c = 22 m/min.

f = 0.2 mm/rev.

$$N = \frac{V \times 1000}{\pi D} = \frac{22 \times 1000}{\pi \times 16} = 438 \text{ rpm}$$

For one hole

$$T = \frac{L}{N \times F} = \frac{30 + (0.29 \times 16)}{438 \times 0.2}$$

$$= \frac{34.64}{87.6} \text{ min.}$$

= 0.39 min.

For 4 holes = 0.39 × 4 = 1.58 min (Ans)

SHAPER

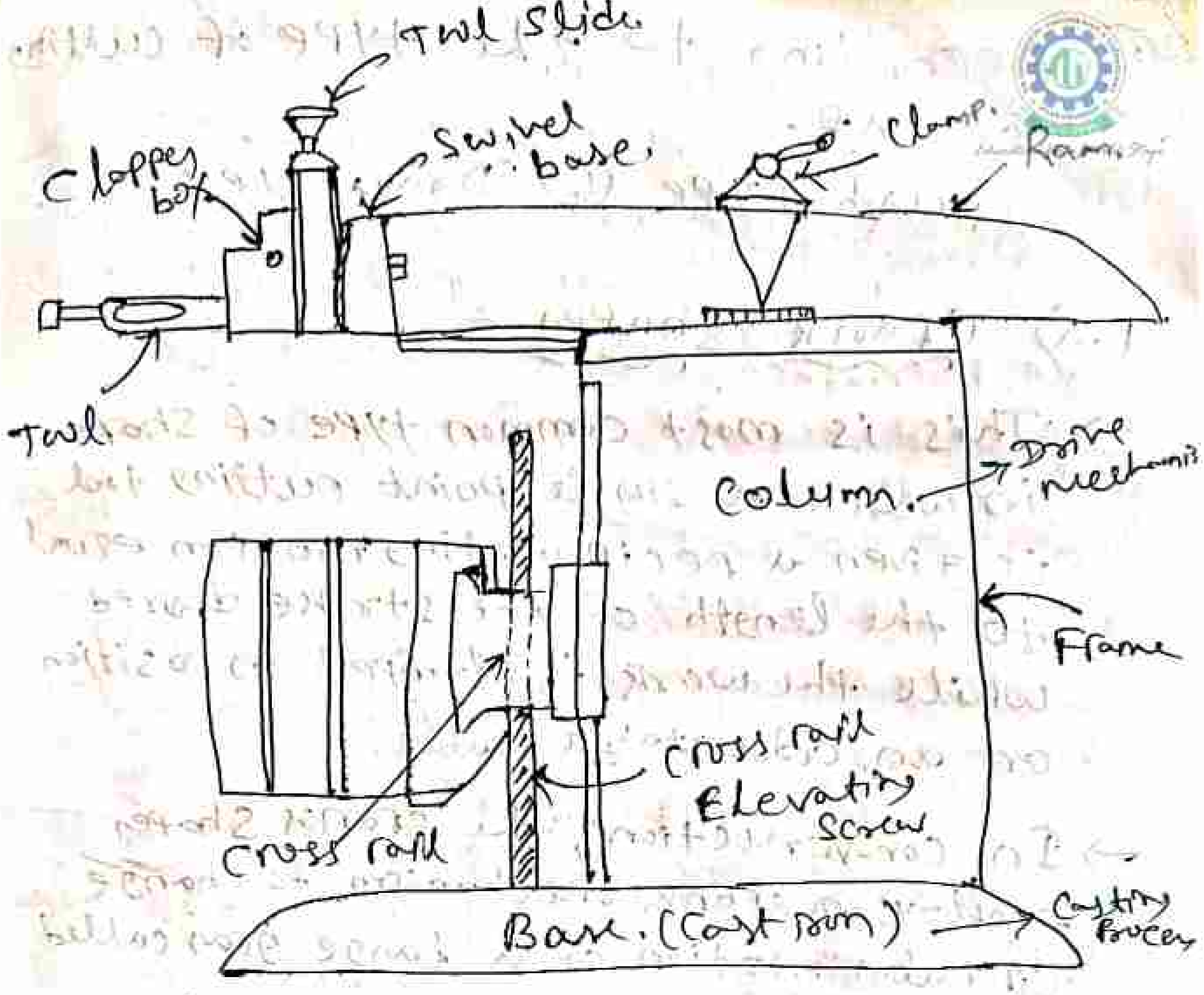
→ Shaper is a reciprocating type of machine tool intended primarily to produce flat surfaces. These surface may be horizontal, vertical or inclined. → making slot, grooves & etc.

* Working principle :-

→ In case of a shaper; the job is rigidly held in a suitable device like a vice or directly clamped on the machine table.

→ The tool is held in the tool post, which is mounted on the ~~ram~~ ~~machine~~ reciprocating ram. The reciprocating motion of the ram is obtained by a quick return mechanism.

→ As the ram reciprocates, the tool cuts the material during its forward stroke. During return, there is no cutting action ~~& the~~ of the ram. Hence it is called idle stroke. The forward & return strokes constitute one operating cycle of the shaper.



Types of shaper

1. According to the type of mechanism used for giving reciprocating motion to the arm.
   (a) Crank type (b) Geared type.
   (c) Hydraulic type.
2. According to position & travel of ram.
   (a) Horizontal type (b) vertical type
   (c) Traveling head type.
3. According to type of design of the table
   (a) Standard shaper (b) Universal shaper.

(4) According to the type of cutting stroke.

(a) push type (b) Draw type.

1.a) Crank shaper :

→ This is most common type of shaper in which a single point cutting tool is given a reciprocating motion equal to the length of the stroke desired while the work is clamped in position on an adjustable table.

→ In construction, the crank shaper employs a crank mechanism to change circular motion of a large gear called "bull gear" incorporated in the machine to reciprocating motion of the ram.

1.b) Geared type :

→ The reciprocating motion of the ram in some type of shaper is effected by means of a rack & pinion.

→ The rack teeth which are cut directly below the ram mesh with a spur gear

→ The pinion meshing with the rack is driven by a gear train.

→ This type of shaper is not very widely used.

1.c) <u>Hydraulic type</u>:

→ In this shaper, reciprocating movement of the ram is obtained by hydraulic power. Oil under high pressure is pumped into the operating cylinder fitted with a piston.

→ The end of the piston rod is connected to the ram. The high pressure oil first acts on one side of the piston & then on the other causing the piston to reciprocate & motion is ~~transfered~~ transmitted to the ram.

→ The piston speed is changed by varying the amount of liquid delivered by the pump. One of the most important advanges of the type of shaper is that the cutting speed & force of the ram drive are constant from the very begining to the end of the cut.

→ It also offers great flexibility of speed & feed control, eliminates shock & permits slip or slowing up of motion when the cutting tool is over loaded, protecting the parts of the tools from breakage.

2.a) Horizontal type :

→ In this shaper, the ram holding the tool reciprocates in a horizontal axis. It is mainly used to produce flat surface.

2.b) Vertical type :

→ In this shaper, the ram holding the tool reciprocates in a vertical axis. In some of vertical machines provision is made to allow adjustment of the ram to an angle of about 10 degree from the vertical position.

→ Vertical shaper may be crank driven, rack driven, screw driven or hydraulic power driven. The work table of a vertical shaper can be given cross, longitudinal & rotary movement.

→ The tool used on a vertical shaper is entirely different from that used on a horizontal shaper.

2.c) Travelling head type :

→ In this shaper, the ram carrying the tool while it reciprocates moves crosswise to give the required feed

→ Heavy & unwidely jobs which are very difficult to hold on the table of a standard shaper & fed past the tool are held static on the basement of the machine while the ram reciprocates & supplies the feeding movements.

3.a) Standard or plain shaper:-

→ A shaper is termed as standard or plain when the table has only two movements, vertical & horizontal, to give the feed. The table may or may not be supported at the outer end.

3.b) Universal shaper:-

→ In this shaper, in addition to the movements provided on the table of a standard shaper, the table can be swivelled about an axis parallel to the ram ways, & the upper portion of the table can be tilted about a second horizontal axis perpendicular to the first axis.

→ As the work mounted on the table can be adjusted in different planes, the machine is most suitable for different types of work & is given the name 'Universal'.

4. a) Push type :-

→ This is the most general type of shaper used in common practice. The metal is removed when the ram moves away from the column. i.e pushes the work.

4. b) Draw type :-

→ In this shaper, the metal is removed when the ram moves towards the column of the machine. i.e draws the work towards the machine.

→ The tool is set in a reversed direction to that of a standard shaper. The ram is generally supported by an overhead arm which ensures rigidity & eliminates deflection of the tool.

→ In this shaper the cutting pressure acts towards the column which relieves the crossrail & other bearings from excessive loading & allows to take deep cuts. Vibration in these machine is pratically eliminated.

* Specification of shaper :-

1. maximum length of the stroke
2. Size of the table.
3. maximum horizontal & vertical travel of the table.

(4) Maximum number of stroke per minute.
(5) Floor space required.
(6) weight.

* Principle parts of a shaper.

(1) BASE :- It is a heavy & robust cast iron body which acts as a support for all the other parts of the machine which are mounted over it.

(2) Column :- It is a box type cast iron body, mounted on the base & acts as a housing for the operating mechanism.

(3) Cross rail :- The cross rail is mounted on the front vertical guideways of the column. It has two parallel guideways on its top in the vertical plane that are perpendicular to the ram axis.

→ The table may be raised or lowered to accomodate different size of jobs by rotating an elevating screw which causes the cross rail to slide up & down on the vertical face of the column.

→ A horizontal cross feed screw which is fitted within the cross rail & parallel to the top guideways of the cross rail actuates the table to move in a crosswise direction.

(4) Saddle :- The saddle is mounted on the crossrail which holds the table firmly on its top. Crosswise movement of the saddle by rotating the crossfeed screw by hand or power causes the table to move sideways.

(5) Table :- The table which is bolted to the saddle receives crosswise & vertical movements from the saddle & cross rail. It is a box like casting having 'T-slot' both on the top & sides for clamping the work. In a universal shaper the table may be swivelled on a horizontal axis & the upper part of the table may be tilted up & down.

(6) Ram :- The Ram is the reciprocat member of the shaper. This is semi cylindrical in form & havily ribbed inside to make it more rigid. It carries the tool head & provide a straight line motion to the tool.

(7) Tool head :- The tool head of a shaper holds the tool rigidly, provides verti & angular feed movement of the tool & allows the tool to have an

automatic relief during its return stroke. The vertical slide of the tool head has a swivel base which is held on a circular seat on the ram. The amount of feed or depth of cut may be adjusted by a micrometer dial on the top of the down feed screw.

Shaper mechanism.

→ In a shaper, rotary movement of the ~~device~~ drive is converted into reciprocating movement by the mechanism ~~obtained~~ contained within the column of the machine. The ram holding the tool gets the reciprocating movement.

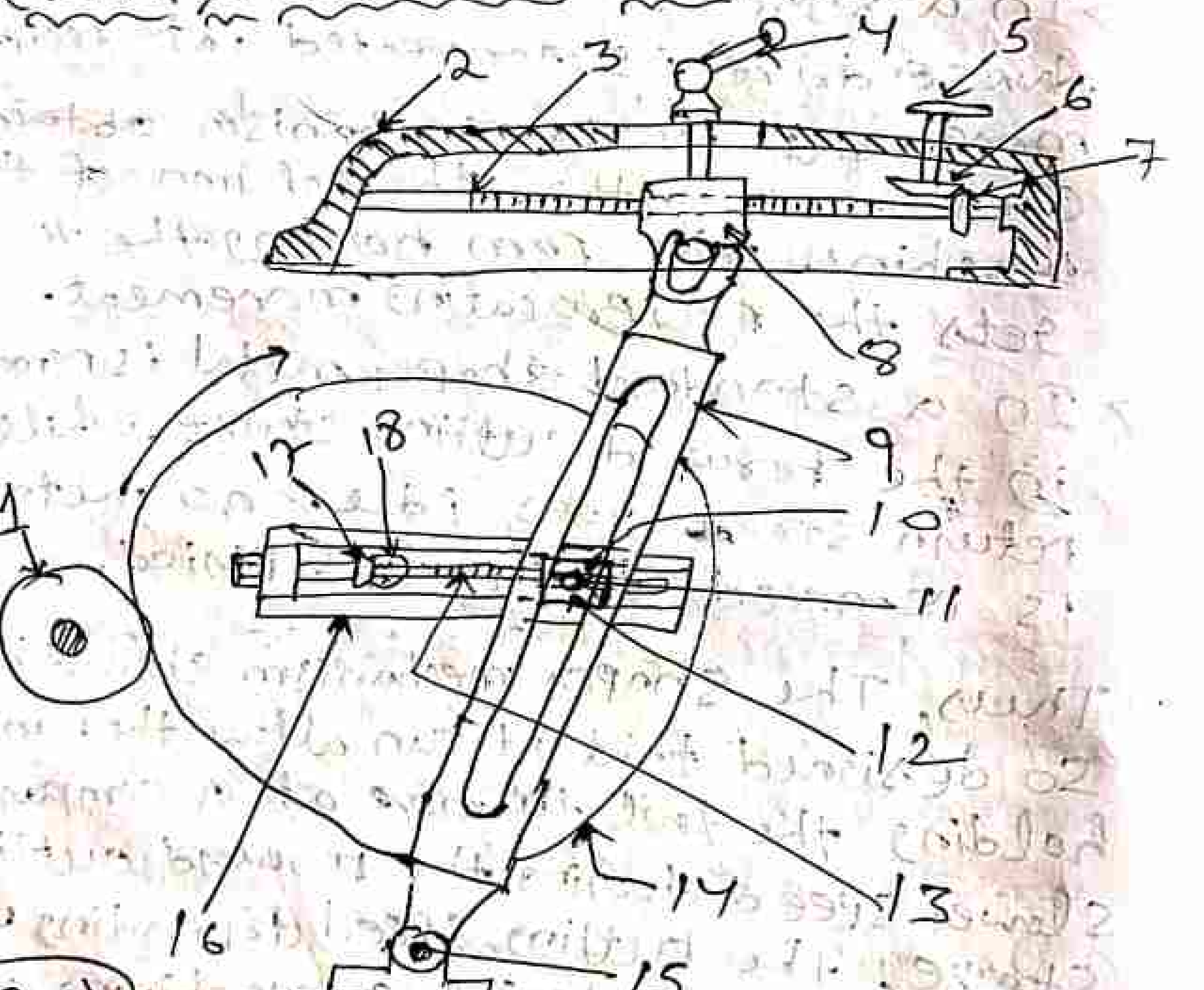
→ In a standard shaper metal is removed in the forward cutting stroke, while the return stroke goes idle & no metal is removed during this period.

→ Thus, The shaper mechanism should be so designed that it can allow the ram holding the tool to move at a comparatively slower speed during the forward cutting stroke, the cutting speed depending upon the type of material & machining condition, whereas during the return stroke it can allow the ram to move at a faster rate to reduce the idle return time. This mechanism is known as "quick return mechanism".

→ The reciprocating movement of the ram & the quick return mechanism of the machine are usually obtained by any one of the following method:

① Crank & slotted link mechanism
② Whitworth quick return mechanism
③ Hydraulic shaper mechanism.

① Crank & slotted link mechanism:



(Fig-1)

1) Driving pinion.
2) Ram
3) Screwed Shaft
4) Clamping lever
5) Handwheel for position of stroke adjustment
6) 7) Bevel gears.
8) Ram block
9) Slotted link or rocker arm.
10) Bull gear sliding block.
11) Crank pin.
12) Rocker arm sliding block.
13) Lead screw.
14) Bull gear
15) Rocker arm pivot.
16) Bull gear slide.
17), 18) Bevel gear

→ The motion of power is transmitted to the bull gear(14) through a pinion(13) which receives its motion from an individual motor or over head line shaft through speed control mechanism.

→ Speed of the bull gear may be changed by different combination of gearing or by simply shifting the belt on the step cone pulley.

→ Bull gear (14) is a large gear mounted within the column. Bolted to the centre of the bull gear is a radial slide 16 which carries a sliding block 10 into which the crank pin (11) is fitted.

→ Rotation of the bull gear will cause the crank pin(11) to revolve at a uniform speed. Sliding block(12) which is mounted upon the crank pin (11) is fitted within the slotted link (9).

→ The slotted link (9) which is also known as the rocker arm is pivoted(15) at its bottom end attached to the frame of the column.

→ The upper end of the rocker arm is forked & connected to the ram block (8) by pin.

→ As the bull gear rotates causing the crank pin(11) to rotate, the sliding block(12) fastened to the crank pin (11) will rotate on the crank pin circle, & at the same time will move up & down the slot in the slotted link (9) giving it a rocking movement which is communicated to the arm. Thus the rotary motion of the bull gear is converted to reciprocating movement of the ram.

* Principle quick return mechanism :

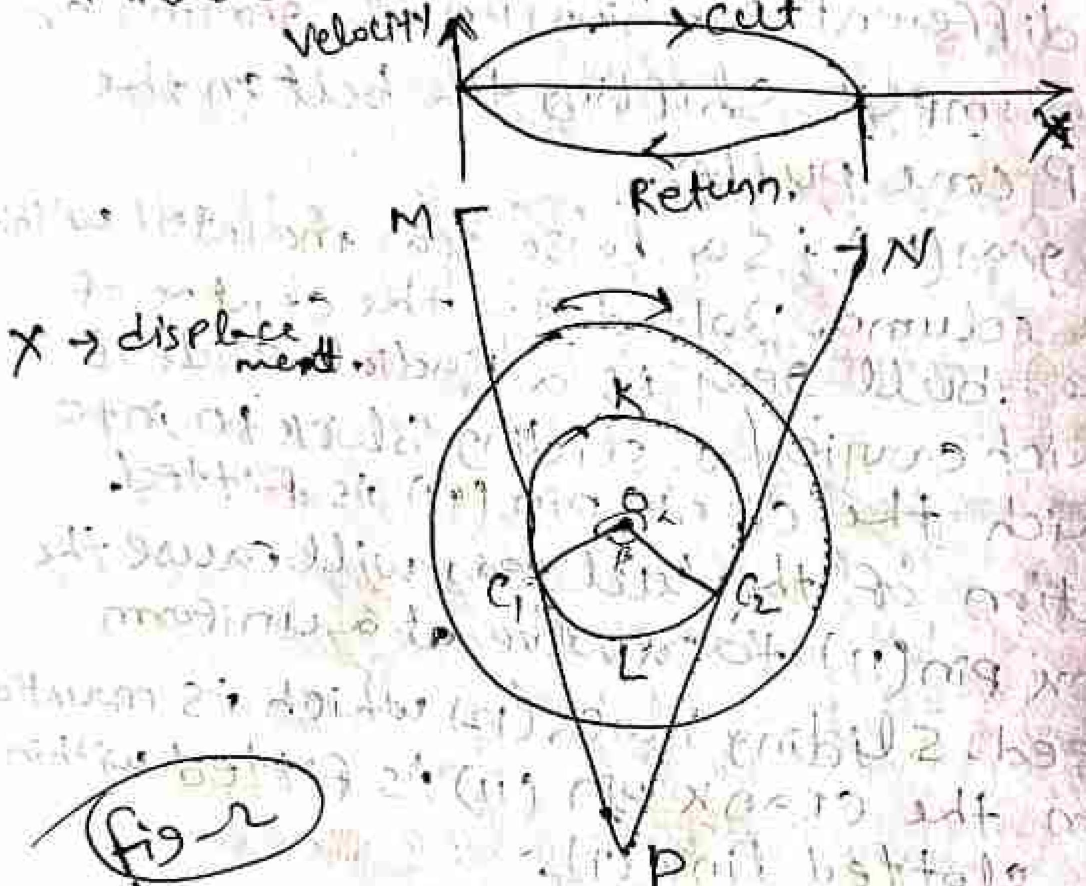


fig-2

→ When the link is in the position PM, the ram will be at the extreme backward position of its stroke, & when it is at PN, the extreme forward position of the ram will have been reached.

→ PM & PN are shown tangent to the crank pin circle.

→ The forward cutting stroke, therefore, takes place when the crank rotates through the angle C_1KC_2 & the return stroke takes place when the crank rotates through the angle $C_2 L C_1$.

→ It is evident that the angle $C_1 K C_2$ made by the forward or cutting stroke is greater than the angle $C_2 L C_1$ described by the return stroke.

→ The angular velocity of the crank pin being constant the return stroke is, therefore, completed within a shorter time for which it is known as quick return motion.

→ The ratio between the cutting time & return time may be determined from the formula:

$$\frac{\text{cutting time}}{\text{Return time}} = \frac{\angle C_1 K C_2 \ (\alpha)}{\angle C_2 L C_1 \ (\beta)}$$

→ Since Return time ($C_2 L C_1$) is smaller than cutting time ($C_1 K C_2$), time taken during the return stroke is less than the forward stroke. The ratio between these two angles & corresponding timing is approximately 3:2.

* Adjusting the length of stroke:

→ The crank pin (11) is fastened to the sliding block (10) which can be adjusted & the radious of its travel may be varied.

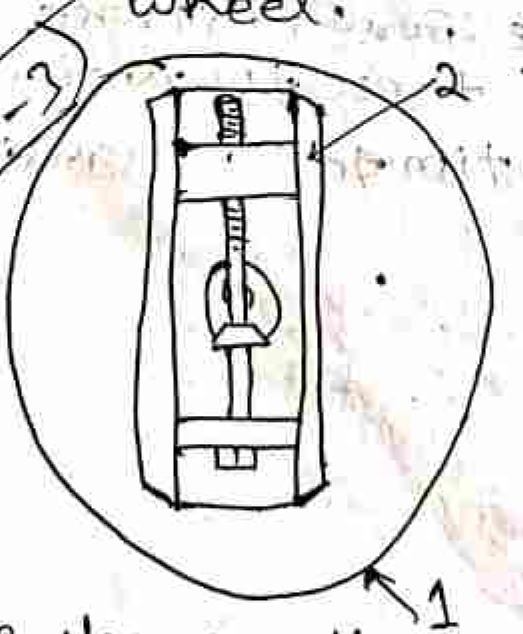
→ The block (10) is again mounted upon the radial slide (16) bolted to the centre of the bull gear (14).

→ The bevel gear (18) placed at the centre of the bull gear may be rotated by a handle causing the bevel gear (17) to rotate.

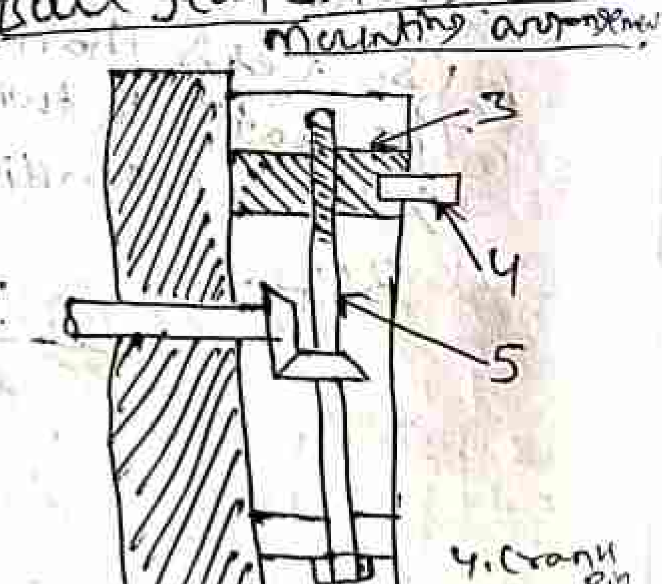
→ The bevel gear (17) is mounted upon the small lead screw (13) which passes through the sliding block (10)

- Thus rotation of the bevel gear (17) will cause the sliding block (10) carrying the crank pin (11) to be brought inwards or outwards with respect to the centre of the bull wheel.

Fig-7



Bull gear sliding block mounting arrangement



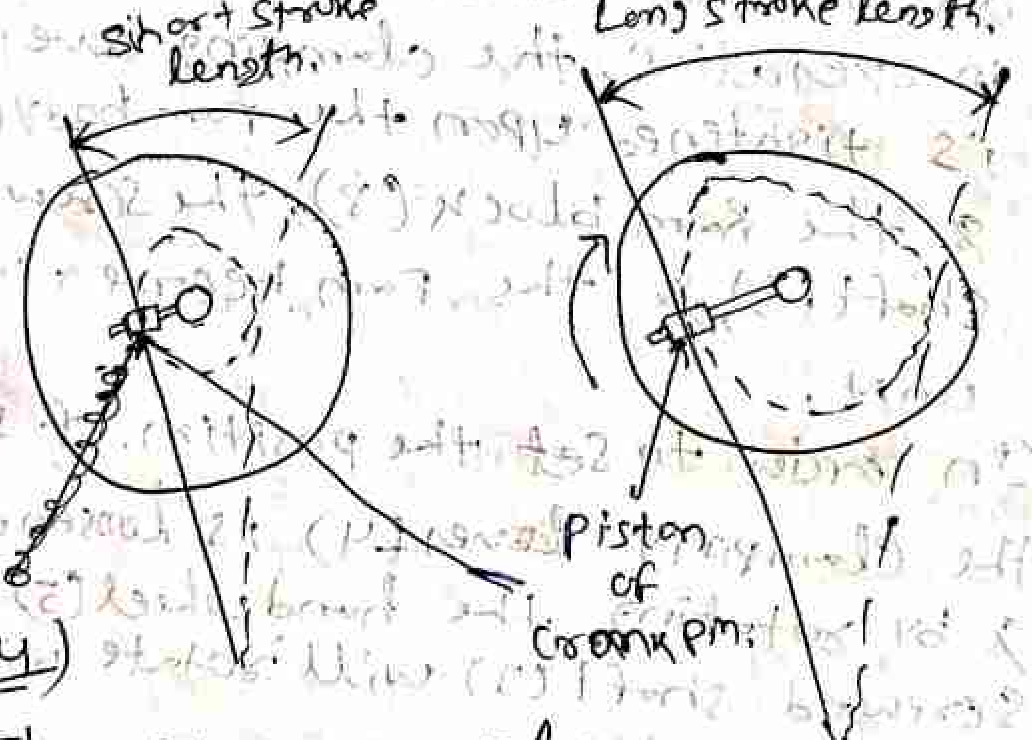
4. Crank pin
5. Lead screw

1. Bull gear 2. Bull gear slide 3. Bull gear sliding block.

→ In (Fig-3) shows the detail arrangement for altering the position of bull gear sliding block on bull gear for adjusting the length of stroke.

→ The sketch has been drawn without the rocker arm in position. The closer the pin is brought to the centre of the bull wheel, the smaller will be the stroke. Maximum stroke of the ram is obtained when the crank pin is shifted towards the farthest end of the slide. Fig-4 shows the short & long stroke of the ram, effected by altering the position of crank pin.

★ ~~Adjusting the position of stroke~~



(Fig-4)

~~→ The crank & slotted link mechanism is shown in Fig-1. The motion or power is transmitted to the "bull gear" (14) through a pinion (1) which receives its motion from an individual motor or overhead line shaft through speed control mechanism.~~

⊗ Speed of the bull gear may be changed by different combination of

* Adjusting the position of stroke:

→ The position of the ram relative to the work can also be adjusted. Referring to the Fig 1, by rotating the hand wheel (5) the screwed shaft (3) fitted in the ram may be made to rotate through two bevel gear (6) & (7).

→ The ram block (8) which is mounted upon the screwed shaft (3) acts as a nut; when the machine is in operation, the clamping lever 4 is tightened upon the ram body (2) & the Ram block (8), the screwed shaft (3), & the ram becomes one unit.

→ In order to set the position of stroke, the clamping lever (4) is loosened & by rotating the hand wheel (5) the screwed shaft (3) will rotate within the ram block.

→ The nut remaining fixed in position rotation of the screwed shaft will cause the ram to move forward or backward with respect to the ram block according to the direction of rotation of the hand wheel (5).

→ Thus the position of ram may be adjusted with respect to the workpiece. The clamping lever (Y) must be tightened after the adjustment has been made.

Machining Time, Cutting Speed, Feed, Depth of Cut:

* Cutting Speed:

$$\text{cutting speed (m/min)} = \frac{\text{length of the cutting stroke (mm)}}{\text{time required by the cutting stroke (min)}}$$

let L = The length of cutting stroke

m = The ratio between return time to cutting time.

n = the number of double strokes of the ram per minute or rpm of the bull wheel.

N = the cutting speed mm/min.

$$\text{Time taken by the cutting stroke (min)} = \frac{\text{length of cutting stroke (mm)}}{\text{cutting speed (m/min)}}$$

$$= \frac{L}{1000 \times V}$$

$$m = \frac{\text{return stroke time}}{\text{cutting stroke time}}$$

return stroke time = m × cutting stroke time.

$$= \frac{m \times L}{1000 \times V}$$

$$\text{cutting stroke time} = \frac{L}{1000 \times V}$$

$$\text{return stroke time} = \frac{m \times L}{1000 \times V}$$

Time taken to complete one double stroke = cutting stroke time + return stroke time

$$= \frac{L}{1000 \times V} + \frac{mL}{1000 \times V}$$

$$= \frac{L(1+m)}{1000 \times V}$$

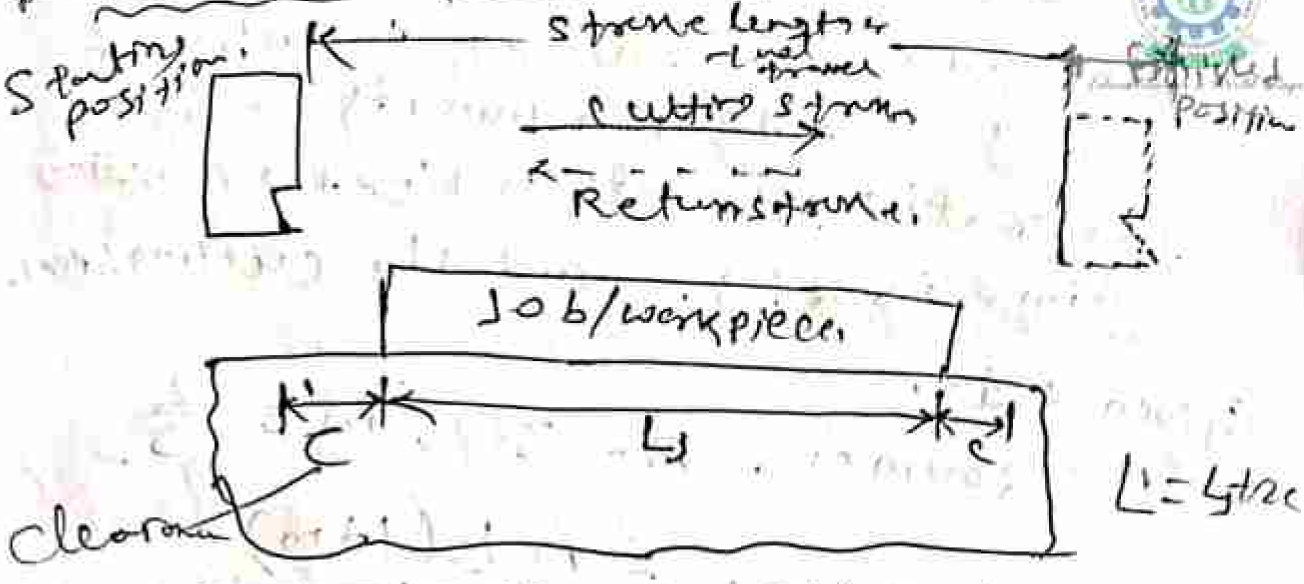
Number of double stroke per min or rpm of the bull wheel

$$= \frac{1}{\frac{L(1+m)}{1000 \times V}}$$

$$n = \frac{1000 \times V}{L(1+m)}$$

$$V = \frac{n L (1+m)}{1000}.$$

Machining time



If the length of cutting stroke, breadth of the job, feed & cutting speed are known, the time required to complete the job may be calculated as.

Let. L = the length of the stroke in mm. ($L = L_1 + 2C$)

B = Breadth of the work in mm.

f = Feed expressed mm/double stroke.

m = the ratio of return time to cutting time.

V = the cutting speed in m/min.

Time taken to complete double stroke $= \frac{L}{1000 \times V}(1+m)$

Total number of double stroke required to complete the job $= \frac{B}{F}$

Total time taken to complete ~~job~~ cut $= \frac{L \times B(1+m)}{1000 \times V \times f}$

Q1) In a shaper work, the length of stroke is 200 mm, number of double stroke per minute is 30 & the ratio of return time to cutting time is 2 : 3. Find the cutting speed.

Given data:

$L = 200\,mm$, $n = 30$, $m = \frac{2}{3}$

$$\text{Cutting speed} = \frac{n\,L(1+m)}{1000}$$

$$= \frac{30 \times 200\left(1+\frac{2}{3}\right)}{1000}$$

$$= 10\ m/min.$$

Q2) Find the time required for taking a complete cut a plate 600×900 mm if the cutting speed is 9 m/min. The return time to cutting time ratio is 1 : 4 & the feed is 3 mm. The clearance at each end is 75 mm.

Given data

$L = 600\,mm$, $B = 900\,mm$, $V = 9\,m/min$, $m = 1:4$, $F = 3\,mm$, $C = 75\,mm$

$$L = 600 + (2\times75) = 600 + 150 = 750\,mm.$$

$$\text{Cutting time} = \frac{L \times 60}{1000 \times V} = \frac{750 \times 60}{1000 \times 9} = 5\ sec.$$

$$m = \frac{\text{Return stroke time}}{\text{Cutting stroke time}} = \frac{1}{4}$$

$$\text{Return stroke time} = 5 \times \frac{1}{4}$$

$$= 5/4 \text{ sec.}$$

$$\text{Total time for one complete double stroke} = 5 + \frac{5}{4}$$

$$= \frac{25}{4} \text{ sec.}$$

$$\text{Total number of double stroke necessary to complete the cut} = \frac{B}{F} = \frac{900}{3}$$

$$= 300$$

$$\text{Total time required to complete the cut} = \frac{25}{4} \times 300 \times \frac{1}{60}$$

$$= 31.25 \text{ mm.}$$

PLANING MACHINE

→ The planer like a shaper is a machine tool primarily intended to produce plane & flat surfaces by a single point cutting tool.

→ A planer is very large & massive compared to a shaper & capable of machining heavy workpiece which cannot be accomodated on a shaper table.

→ The fundametal difference between a shaper & a planer is that in a planer the work which is supported on the table, reciprocates past the stationary cutting tool & the feed is supplied by the lateral movement of the tool, whereas in a shaper the tool is mounted upon the ram reciprocates & the feed is given by the cross wise movement of the table.

→ In this machine, the table called 'platen', on which the work is securely fastened, has a reciprocating motion.

→ The tool head is automattically fed horizontal in either direction along the heavily supported cross rail over the work, & automatic feed is also provided.

Advantages of Planer:-

(i) Can take much heavier cuts.
(ii) Larger work can be handled.
(iii) This work is mounted on a table which is supported throughout its entire movement, so a maximum support is obtained.
(iv) No work or tool deflection or distortion. (since there are no overhanging parts such as a ram)

Working principle:-

→ The workpiece is clamped on to a planer table with the help of special bolts that fit in the T-slot of the table, & provide a means for positioning & securely holding the workpiece. The table rides over V-grooves on the bed of the planer & is accurately guided as it travels back & forth.

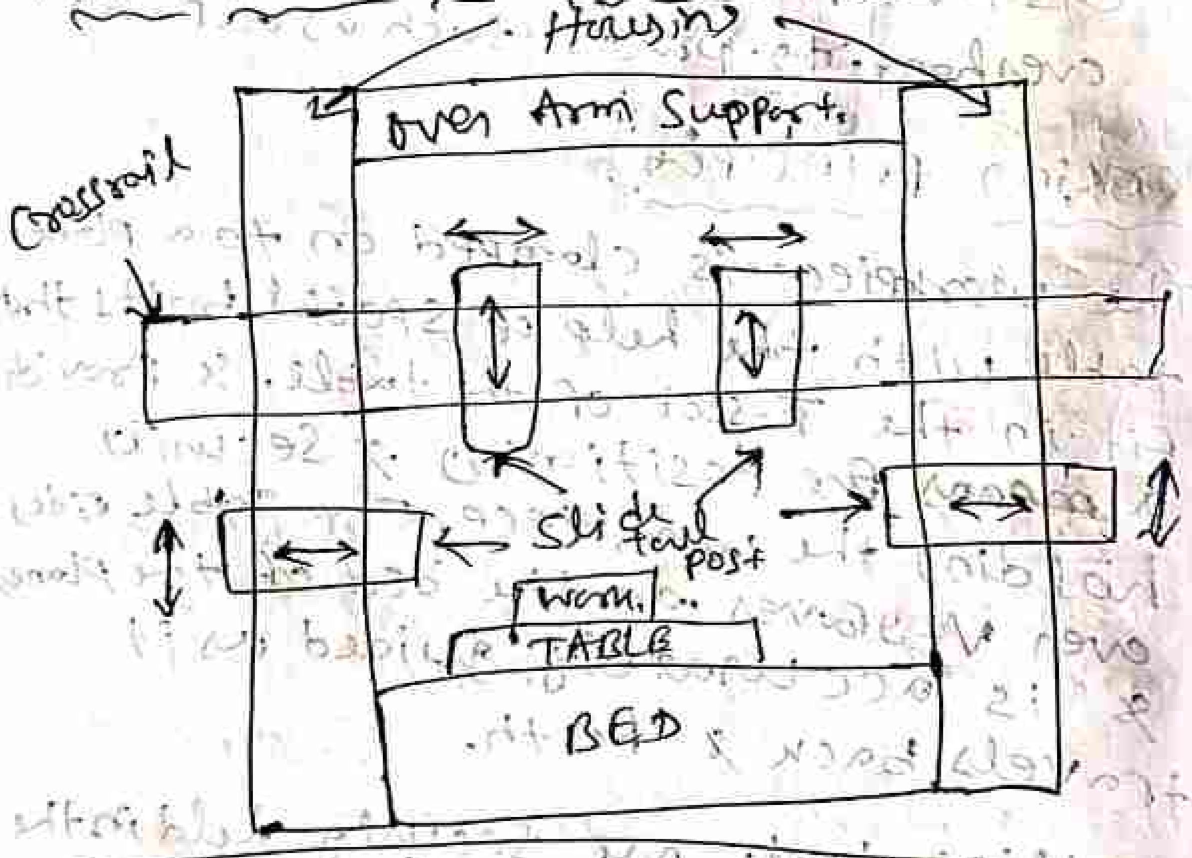
→ Cutting tools are securely held in the tool heads mounted on the housing & can be moved vertically or horizontally from side to side. The tool heads are also mounted on a horizontal cross-rail that can be moved up & down.

→ Use of multiple tool heads permits simultaneous machining of more than one surface of the workpiece & increases productivity.

Specification :-

(i) Horizontal distance between two vertical column.
(ii) Vertical distance between the table top & crossrail.
(iii) Maximum length of the table.

Main parts of Planer machine



Housing (column) → Driving mechanism.

1. BED
2. TABLE
3. HOUSING OR COLUMNS.
4. CROSS-RAIL
5. TOOL HEADS.

(1) BED :- It is a very large & heavy cast iron structure which supports the whole structure of the machine over it.

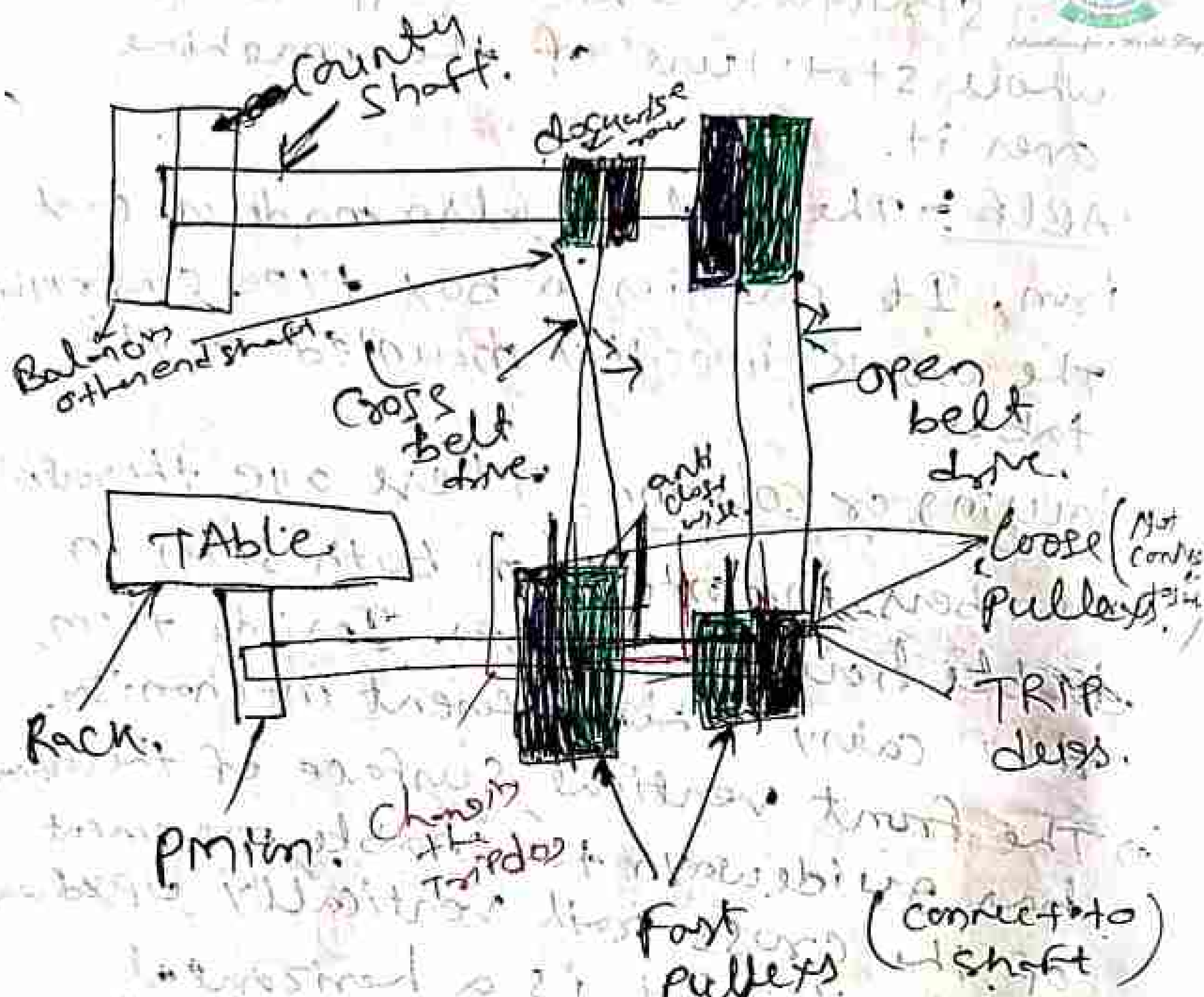
(2) TABLE :- The table is also made of cast iron. It carries a box type construction. The work directly mounted on the table.

(3) Housing or column :- These are the vertical members mounted on both sides in double housing planer. Inside them, they carry the different mechanism.
→ The front vertical surface of the column has guideways to enable movement of the cross rail vertically up & down.

(4) Cross-rail :- It is a horizontal member of heavy structure, which connects the two vertical housing of the machine. By means of elevating the screw it can be moved up & down. It carries two vertical tool heads.

(5) Tool heads :- Four Tools heads can be fitted in a planer & any or all of them can be used at a time. Two tool heads can be fitted in vertical position on the cross rail & the other two on the vertical column. Each column carries one side tool head.

* Driving mechanism of Planner



PLANER	SHAPER
(1) It is a heavier, more rigid & costlier machine.	(1) It is a comparatively lighter & cheaper machine.
(2) Machine requires more floor Area.	(2) Machine requires less floor Area
(3) It is used for more large flat surface	(3) It is also used for same purpose but for relatively smaller surface.
(4) ~~The work is directly~~ clamped on the table.	(4) ..

PLANER	SHAPER
(4) Work reciprocates horizontally.	(4) Tool reciprocates horizontally.
(5) Heavier cuts & coarse feeds can be employed.	(5) Very heavy cuts & coarse feeds cannot be employed.
(6) Work setting requires much of skill & takes a longer time.	(6) Clamping of work is simple & easy.
(7) Several tools can be mounted & employed simentaneously, usually for as a maximum, facilitating a faster rate of Production.	(7) Usally one tool is used on a Shaper.

(8)

* MILLING *

→ A milling machine is a machine tool that removes metal as the work is fed against a rotating multi-point cutter.

→ The cutter rotates at a high speed & because of the multiple cutting edges it removes metal at a very fast rate. The machine can also hold one or more number of cutter at a time.

→ The teeth of the cutter removes the metal in the form of chips from the surface of the work to produce the desired shape.

Types of Milling machine :-

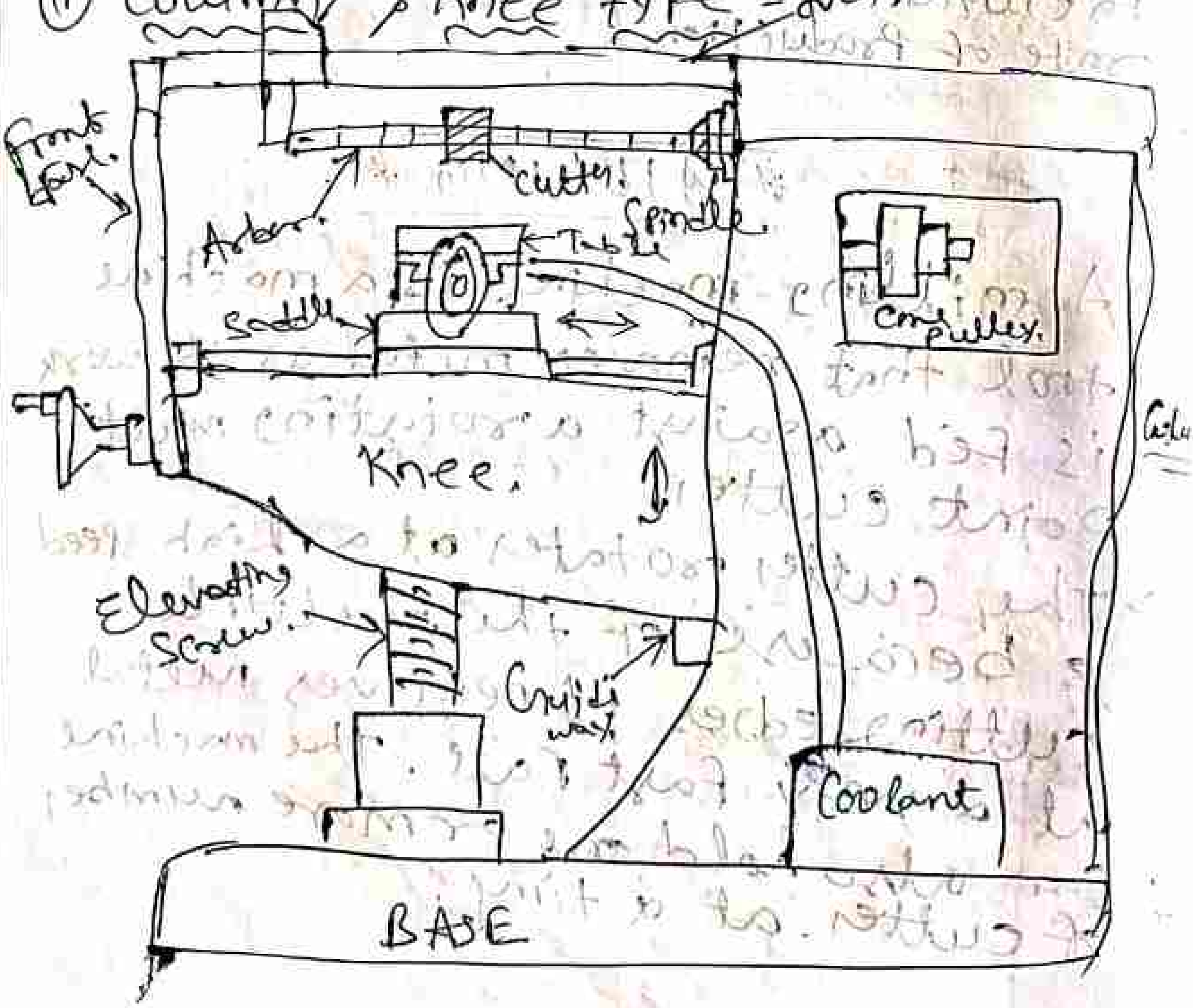
① Column & Knee type.

② Fixed bed or manufacturing type.

③ Planer type.

④ Special purpose type.

① Column & Knee type :-



→ For general purpose work the most commonly used the column & knee type milling machine where the table is mounted on the knee casting which is turn is mounted on the vertical slides of the main column.

→ The knee is vertical adjustable on the column so that the table can be moved up & down to accomodate work of various heights.

(i) Plain or Horizontal Milling machine

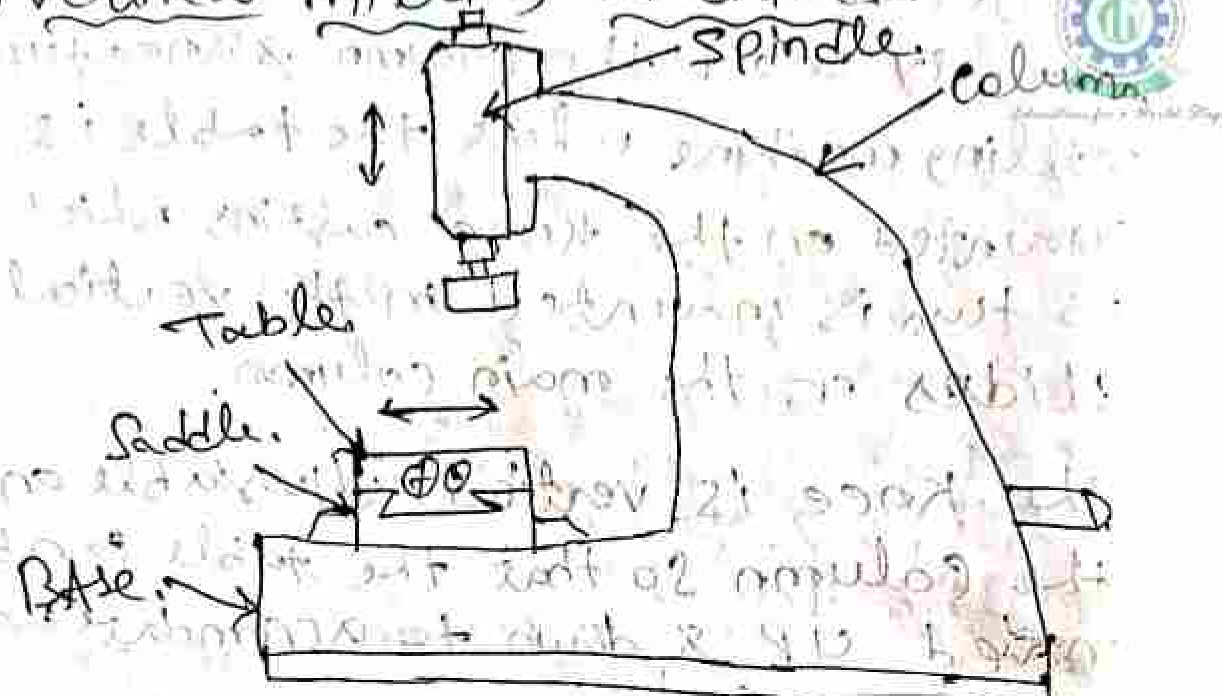
→ The plain milling machines are much more rigid & study that hand milles for accomodating heavy workpiece.

→ The milling machine table may be fed by hand or power against a rotating cutter mounted on a horizontal arbor.

→ A plain milling machine, having horizontal spindle, is also named as horizontal spindle milling machine.

→ In this machine, the table may be fed in a longitudinal, cross or vertical directions.

(ii) Vertical milling machine :-



→ A vertical milling machine can be distinguished from a horizontal milling machine by the position of its spindle which is vertical or perpendicular to the work table.

→ The machine may be of plain or universal type & has all the movements of the table for proper setting & feeding the work.

→ The spindle head which is clamped to the vertical column may be swivelled at an angle, permitting the milling cutter mounted on the spindle to work on angular surface.

→ The end mills & face milling cutters are the usual tools mounted on the spindle.

(iii) Hand milling machine.

→ The simplest of all types of milling machine is the hand milling machine. in which the feeding movement of the table is supplied by hand movement of operator.

→ The cutter is mounted on a horizontal arbor & is rotated by power, the machine is relatively smaller in size than that other types. of & is particularly suitable for light duty & simple milling operations such as machining slots, grooves. & keyways of smaller dimensions.

(iv) Universal milling machine :-

→ A universal milling machine is so named because it may be adpted to a very wide range of milling operations.

→ A universal milling machine can be distinguished from a plain milling machine in that the table of a universal milling machine is mounted on a circular swivelling base which has degree graduations, & the tale can be swivelled to any angle upto 45° on eithe side of the normal position.

→ The table can be swivelled about a vertical axis & set an angle other than right angles to the spindle.

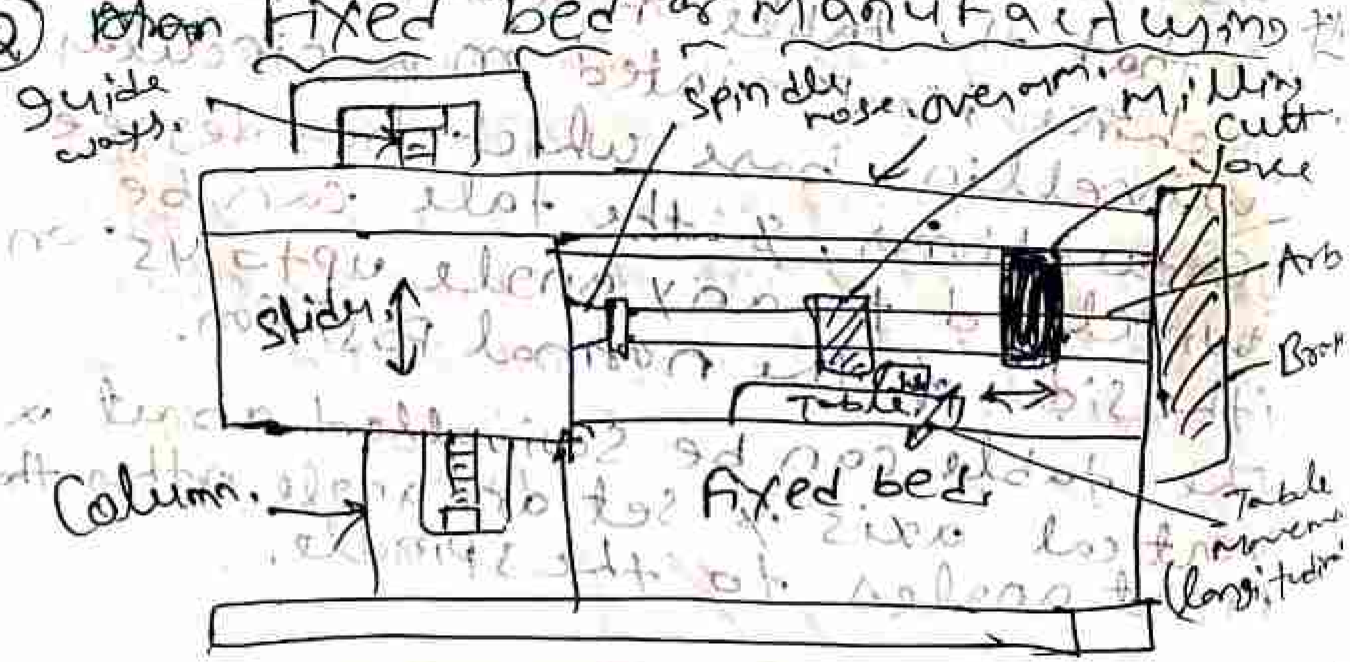
→ Thus in a universal milling machine, the table to three movements as in a plain milling machine, in addition to three movements the table may have a fourth movement when it is fed at an angle to the milling cutter.

→ This additional feature enables it to perform helical milling operation which cannot be done on a plain milling machine unless a spiral milling attachment is used.

→ The capacity of a universal milling machine is considerably increased by the use of special attachments such as dividing head, rotary attachment & slotting attachment, etc.

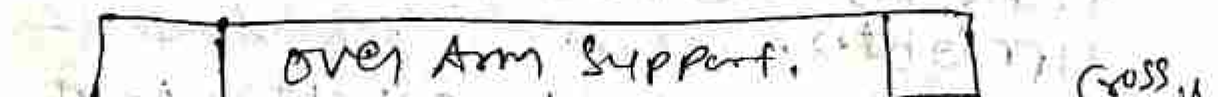
→ The machine can produce spur, spiral bevel gears, twist drills, reamers, milling cutters etc. besides doing all conventional milling operations.

② Fixed bed or manufacturing



→ The fixed bed type milling machines are comparatively large, heavy, & rigid & differ from column & knee type milling machine by the construction of its table mounting. The table is mounted directly on the ways of fixed bed. The table movement is restricted to reciprocation at right angles to the spindle axis with no provision for cross or vertical adjustment.

② planer type :-



⇒ The plano-miller, as it is called, is a massive machine built up for machining heavy duty work, having spindle heads adjustable in vertical in transverse directions.

→ It resembles a planer & like a planing machine, it has a cross rail capable of being raised or lowered carrying the cutters their heads, & the saddles, all supported by rigid uprights.

→ There may be a number of independent spindle carrying cutters on the rail as well as two heads on the uprights.

~~This's arrangement of independently spindle driving multiple cutters on the rail as well as two heads on the uprights.~~

→ This's arrangement of independently driving multiple cutter spindles enables number of work surfaces to be machined simultaneously, thereby obtaining great reduction in production time.

→ The essential difference between a planer & a plano milling lies in the table movement. In a planer moves to give the cutting speed, but in a plano milling machine the table movement gives the feed. Hence the table movement in a plano-milling machine is much slower than that of a planning machine.

principal. Parts.

① BASE :- The base of the machine is a grey iron casting accurately machined on its top & bottom surface & serves as a foundation member for all the parts which rest upon it. It carries the column at its one end. In some machines, the base is hollow & serves as a reservoir for cutting fluid.

② Column :- The column is the main supporting frame mounted vertically on the base. The column is box shaped, heavily ribbed inside & houses all the driving mechanisms for the spindle & table feed.
→ The front vertical face of the column is accurately machined & is provided with dovetail guideways for supporting the knee. The top of the column is finished to hold an overarm that extends outward at the front of the machine.

③ Knee :- The knee is a rigid grey iron casting that slides up & down on the vertical ways of the column face. The adjustment of height is effected by an elevating screw mounted on the base that also support the knee.
→ The knee houses the feed mechanism of the table, & different controls to operate it. The top face of the knee forms a slide way for the saddle to provide the cross travel of the bed.

(4) TABLE :- The table rest on ways on the saddle & travels longitudinally. The top of the table is accurately finished & T-slots are provided for clamping the work & other fixtures on it. A leadscrew under the table engages a nut on the saddle to move the table horizon. by hand or power.

(5) over hanging arm. :- This is mounted on the top of the column extends beyond the column face & serves as a bearing support for the other end of the arbor. The arm is adjustable so that the bearing support may be provided nearest the cutter.

(6) Front brace :- It is an extra support that is fitted between the knee & the overarm to ensure further rigidity to the arbor & the knee. The front brace is slotted to allow for the adjustment of the height of the knee relative to the overarm.

(7) Spindle :- This is located in the upper part of the column & receives power from the motor through belts, gears, clutches & transmit it to the arbor. The front end of the spindle just projects from the column face & is provided with a tapered hole into which various cutting tools & arbor may be inserted.

(8) Arbor → An arbor may be considered of the machine spindle on which milling cutters are securly mounted & rotated; The arbors are made with taper shank for proper alignment with the machine spindles having taper holes at their nose.

→ The arbor may be supported at the farthest end from the over hanging arm or may be of cantilever type which is called stub arbor.

*Milling machine mechanism:

→ The milling machine mechanism is composed of spindle drive mechanism & the table feed mechanism.

→ The spindle drive mechanism is incorporated in the column. All modern machines are driven by individual motors housed with in the column, & the spindle receive power from a combination of gears & clutch assembly. Multiple speed of the spindle may be obtained by altering the gear ratio.

→ The power feed mechanism contained within the knee (A) of the machine to enable the table (C) to have three different feed movement, i.e longitudinal, cross & vertical.

→ The power is transmitted from the feed gear box (1+) consisting of change gear to shaft (23) in the knee (A) of the machine by a telescopic shaft (11). Both ends of the shaft (11) are provided with universal joint (10) & (12).

→ Telescopic shaft & universal joints are necessary to allow vertical movement of the knee (A), gear (14), attached to the jaw clutch (20), is keyed to the shaft (23) & drives gear (13) which is free to rotate on the extreme end of the cross feed screw (7).

→ Bevel gear (22) is free to rotate on shaft (23) & is mesh with gear (19) fastened to the elevating screw (15). 16 serves as a nut for 15 and as a screw in nut (17). (15) & (16) therefore serve as a telescopic screw combination & a vertical movement of the knee is thus possible.

→ As soon as the clutch (20) is engaged with the clutch attached to the bevel gear (22) by means of a lever (4) (22) rotates & this being in mesh with gear (19) causes the elevating screw (15) to rotate in (16) giving a vertical movement of the knee.

→ Like-wise, when the clutch (21) which is keyed to the cross feed screw (7) is engaged with the clutch attached to gear (13), power comes to the screw (7) through gear (14) & (13). This causes the screw (7) to rotate in nut (6) of the clamp bed giving a cross feed movement of the clamp bed (D) & saddle (B).

→ Gear (18) is fastened to shaft (23) & meshes with gear (25) which is fastened to the bevel gear (24). Again (24) meshes meshes with gear (5) attached to a vertical shaft which carries at its upper end another bevel gear (3).

→ Gear (3) meshes with gear (2) which is fastened to the table feed screw (1). Therefore, longitudinal feed movement of the table is possible through gears (18), (25), (24), (5), (3) & (2).

*** Milling cutter material:-**

→ The milling cutters may be made of high speed steel, non-ferrous cast alloys or cemented carbide tipped.

→ The highspeed steel cutters are the most widely used cutters in general shop work.

Fundamentals of the milling Process

① Peripheral milling :-

→ The peripheral milling is the operation performed by a milling cutter to produce a machined surface parallel to the axis of rotation of the cutter.

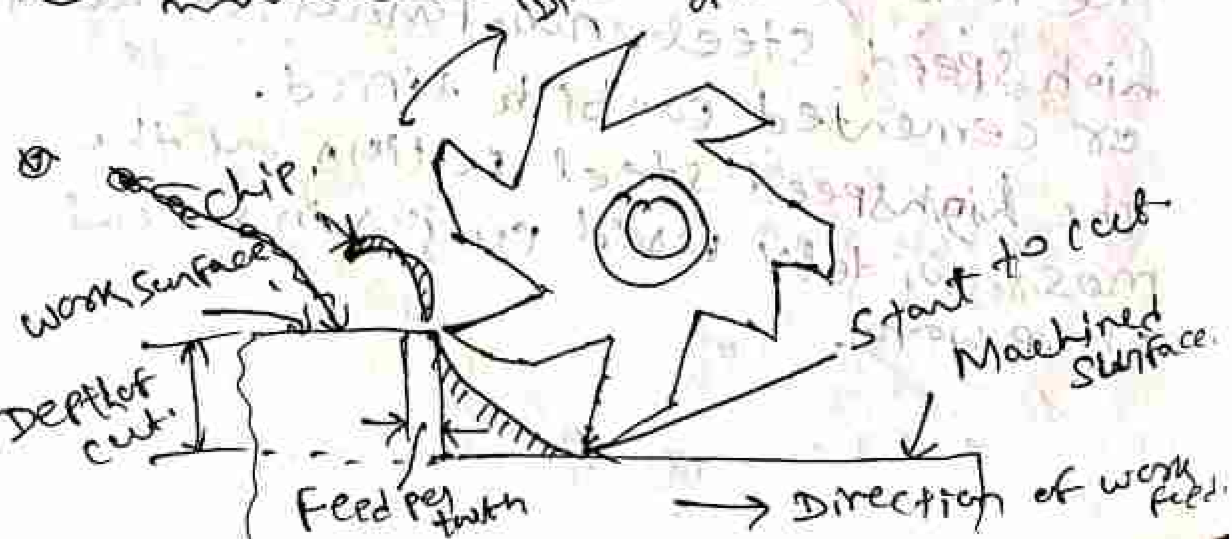
→ In this milling the cutting force is not uniform throughout the length of the cut by each tooth. Due to this reason, a shock is developed in the driving mechanism of the machine that leads to vibration.

→ The quality of surface generated & the shape of chip formed is dependent upon the rotation of the cutter relative to the direction of feed movement of the work.

→ According to the relative movement between the tool & the work, the peripheral milling is classified under two headings.

ⓐ Up milling ⓑ Down milling.

ⓐ Up milling :-



→ The upmilling, which is also called
conventional milling, is the processes
of removing metal by a cutter which is
rotated against the direction of travel
of the workpiece.

The thickness of the chip in upmilling is
→ minimum at the beginning of the cut &
it reaches to the maximum when the cut
terminates.

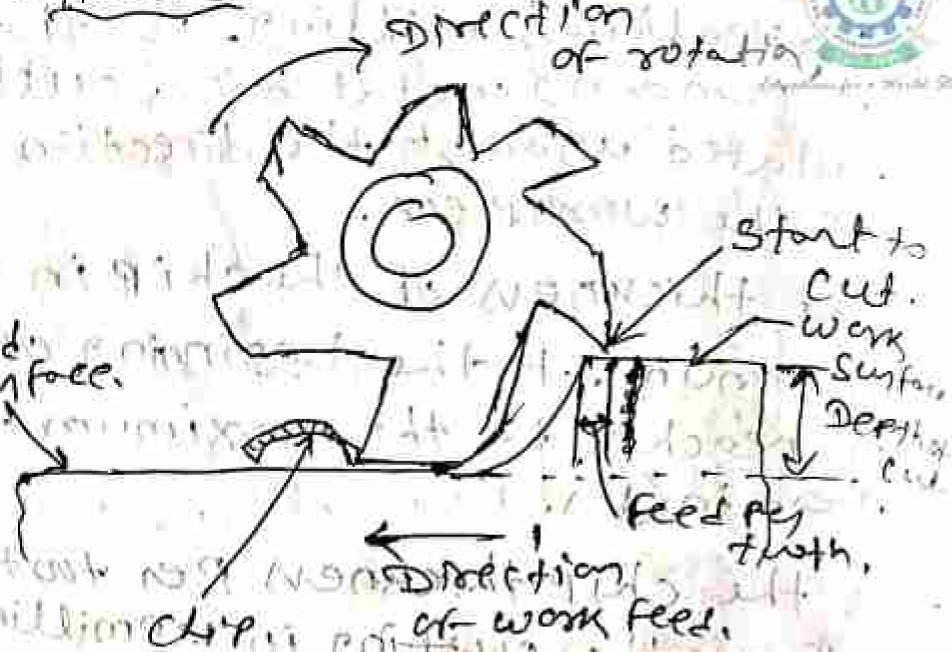
→ As the chip thickness per tooth is not
uniform, the cutting in upmilling increases
from zero to the maximum value per
tooth movement of the cutter. The cutting
force is directed upwards & this tends
to lift the work from the fixtures.

→ In upmilling, due to the typical nature
of the cut, difficulty is experienced in
pouring coolant just on the cutting edge
from where the chip begins.

→ As the cutter progresses, the chip accumulate
at the cutting zone, & may be carried over
with the cutter spoiling the work surface.
The surface milled by upmilling appears
to be slightly ~~wavy~~ wavy as the cutter
teeth do not begin their cut as soon as
they touch the work surface.

→ The teeth slide through a minute distance
at the beginning & then the cut is started.

(b) Down milling



→ The down milling, which is also called climb milling, is the process of removing metal by a cutter which is rotated in the same direction of travel of the workpiece.

→ The thickness of the chip is maximum when the tooth begins its cut & it reduces to the minimum when the cut terminates. The cutter tooth starts removing metal immediately on reaching the work surface, without sliding as it can apply a sufficient bite on the work.

→ The cutting force in down milling is also variable throughout the cut, it is maximum when the tooth begins its cut & it reduces to the minimum when the tooth leaves the work.

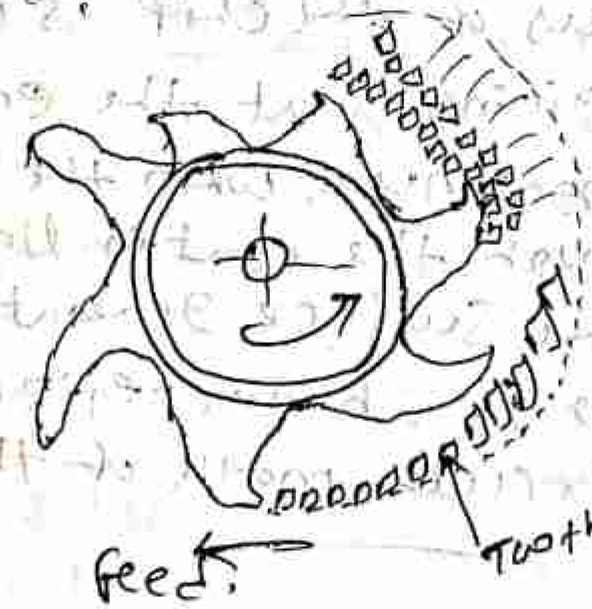
→ In down milling, the fixture design becomes easier as the direction of the cutting force is such that it tends to seat the work firmly in the work holding devices. The chips are also disposed off easily & do not interfere with the cutting. The coolants can be poured directily at the cutting zone where the cutting force is maximum.

→ The downmilling operation having so many advantages. but can not be used on old machines due to the backlash error that may be present between the feed screw of the table & the nut.

→ The backlash error causes the work to be pulled below the cutter when the cut begins & leaves the work free when the cut is terminated. The same action is repeated as soon as the next tooth engages the work.

→ This results in vibration to be set up in the workpiece & damages the work surface. considerably. The down milling should only be performed on rigid machines provided with backlash eliminator.

② Face milling :-



→ The face milling is the operation performed by a milling cutter to produce a flat machine surface perpendicular to the axis of rotation of the cutter.

→ The peripheral cutting edges of the cutter do the actual cutting whereas the face cutting edges finish up the work surface by removing a very small amount of material.

→ In face milling operation both the up & down milling may be considered to be performed simultaneously on the work surface.

→ When the cutter rotates through half of revolution, the direction of movement of the cutter tooth is opposite to the direction of feed & the condition reverses when the cutter rotates through other half of the revolution.

→ The thickness of the chip is minimum at the begining & at the end of cut, & it is maximum when the work passes through the center line of the cutter. The surface generated in face milling is characterized by the tooth circular mark of the cutter.

* Calculation of machining Time :-

$$T = \frac{L}{S_z \times Z \times N}$$

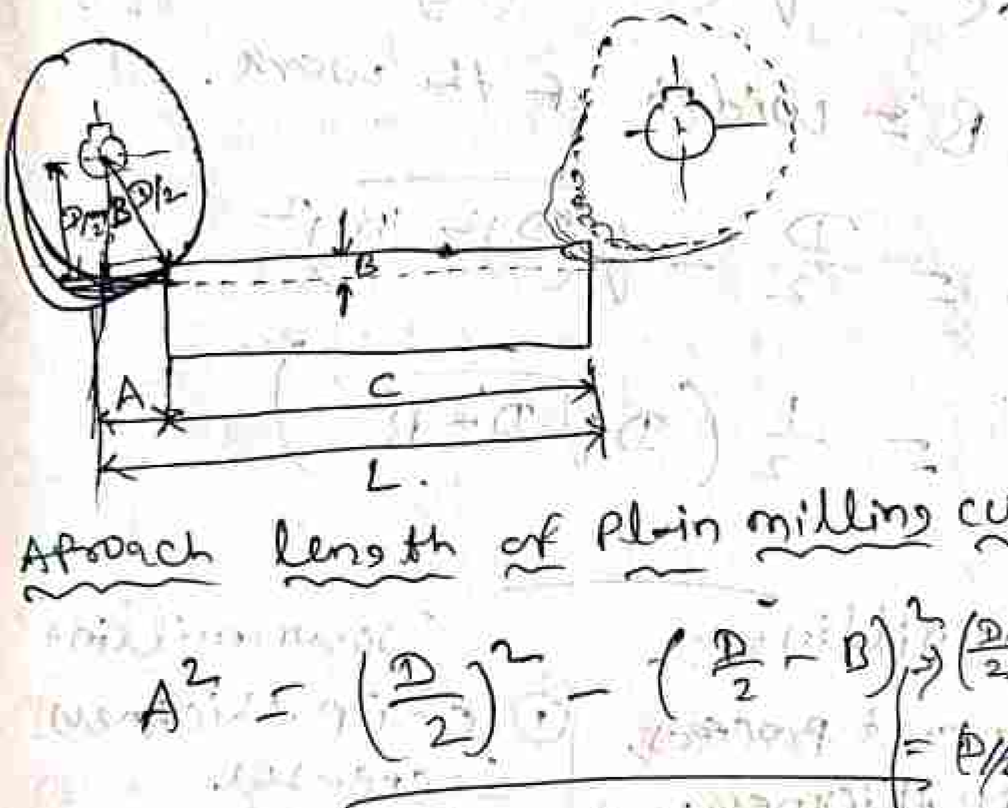
where T = The time required to complete the cut in (minutes)

L = the length of the table travel to complete the cut in (mm.)

S_Z = The feed per tooth in (mm)

Z = The number of teeth in the cutter.

N = The R.P.M. of the cutter.



Approach length of Plain milling cutter.

$$A^2 = \left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - B\right)^2 \Rightarrow \left(\frac{D}{2}\right)^2 - \left[\left(\frac{D}{2}\right)^2 + (B)^2 - 2 \cdot \frac{D}{2} \cdot B\right]$$

$$= (D/2)^2 - (D/2)^2 - B^2 + BD = BD - B^2$$

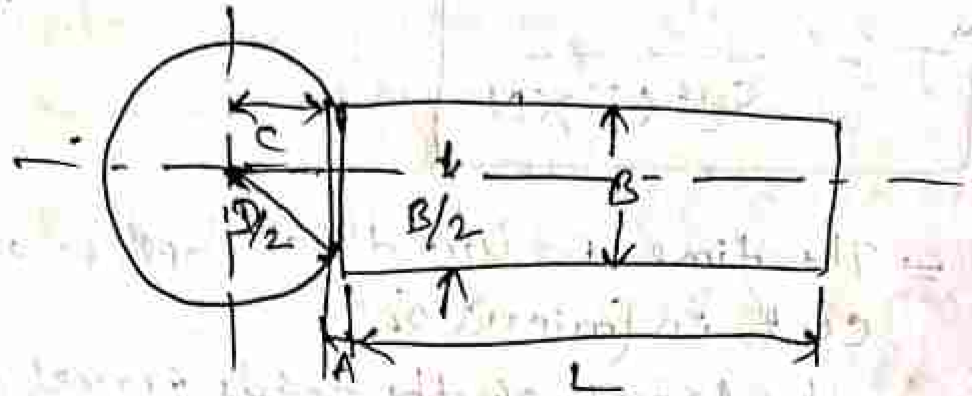
$$A = \sqrt{B(D - B)}$$

A = the approach in (mm)

B = the depth of the cut in (mm)

D = the diameter of the cutter in (mm)

* Approach length for face milling



$$A = D/2 - C$$

D = Diameter of the cutter.

$$C = \sqrt{\left(\frac{D}{2}\right)^2 - \left(B/2\right)^2}$$

B = width of the work.

$$A = \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(B/2\right)^2}$$

$$= \frac{1}{2}\left(D - \sqrt{D^2 - B^2}\right)$$

UP milling	Down milling
① As the cut proceeds, the chip thickness increases gradually.	① chip thickness decreases.
② chip thickness is min^m at begining & max^m at the end of the cut.	② max^m at begining & min^m at end of the cut
③ Rough as compared to down milling.	③ It gives better surface finish.

Up milling	Down milling
(4) Extra clamping force required to fix the Job.	(4) Forces are enough on Job to press down.
(5) cutter turns against the direction of feed.	(5) cutter turns in similar direction of feed.
(6) It is feasible.	(6) It is unfeasible.

* GRINDING MACHINE *

→ Grinding is a process of removing material by the abrasive action of a revolving wheel on the surface of a workpiece, in order to bring it to required shape & size.

→ The wheel used for performing the grinding operation is known as grinding wheel. It consists of a sharp crystals called abrasives, held together by a binding material called bond.

→ It is finishing operation & a very small amount of material removed from the surface during operation.

*. Kinds of Grinding.

Grinding may be classified broadly into two groups.

(1) Rough or non-precision grinding.
(2) Precision grinding.

① Rough or non-precision grinding

→ The common forms of rough grinding are snagging & off hand grinding where the work is held in the operator's hand. The work is pressed hard against the wheel, or vice-versa. The accuracy & surface finish obtained are having secondary importance.

→ Snagging is done where a considerable amount of metal is removed without regard to the accuracy of the finished surface.

→ eg → Snag grinding are trimming the surface left by sprues & risers on casting grinding the parting line left on castings, removing flash on forgings, the excess metal on welds cracks & imperfection on alloy steel billets.

② Precision grinding.

→ This is concerned with producing good surface finish & high degree of accuracy. The wheel or work both are guided in precise paths.
Grinding, in accordance with the type of surface to be ground, is classified as.
ⓐ External cylindrical grinding. ⓑ Internal cylindrical grinding
ⓒ Surface grinding. ⓓ Form grinding.

ⓐ External cylindrical grinding :-

→ Produces a straight or tapered surface on a workpiece. The workpiece must be rotated about its own axis between centers as it passes lengthwise across the face of a revolving grinding wheel.

ⓑ Internal cylindrical Grinding :-

→ Produces internal cylindrical holes & tapers. The workpiece are chucked & precisely rotated about their own axis. The grinding wheel or in the case of small bore holes, the cylinder wheel rotates against the sense of rotation of the workpiece.

ⓒ Surface Grinding :-

→ Produces flat surface, The work may be ground by either the periphery or by the end face of the grinding wheel. The workpiece is reciprocated at a constant speed below or on the end face of the grinding wheel.

ⓓ Form grinding :-

→ It is performed with a grinding wheel which having a particular type of formed surface, that particular shape of wheel is formed over the workpiece. Form grinding should be performed with great accuracy.

Advantages of Grinding Process

1. It is possible to achieve very accurate dimensions & smoother surface finish in a very short time.
2. It is the only method of removing material from materials after hardening.
3. Owing to large number of cutting edges on the grinding wheel, it is possible to produce extremely smooth surface desirable at contact & bearing surfaces by grinding operation.
4. Complex profiles can be produced accurately with relatively inexpensive turning templates.
5. Grinding unlike conventional machining need not cut through the hard skin of forging etc.
6. Since the grinding wheel has considerable width therefore no marks as a result of feeding are there.
7. In this process little pressure is required, thus permitting its use on very light work that would otherwise tend to spring away from the tool. This characteristic permits the use of magnetic block for holding the work in many grinding operation.

* Specifications of Grinding machine

(i) The largest workpiece which can be held on a grinder.
(ii) The normal capacity or power of the grinder
(iii) The width of the table.
(iv) The maximum traverse of the table.
(v) wheel diameter.
(vi) Height of the grinding head.

* The grinding wheel.

→ A grinding wheel is a multi tooth cutter made up of many hard ~~Plast~~ particles. Known as abrasive which have been crushed to leave sharp edges which do cutting.

→ The abrasive grains are mixed with a suitable bond which acts as a matrix or holder when the wheel is in use. The wheel may consists of one piece or of segments of abrasive blocks built up into a solid wheel.

* Abrasives :-

→ An abrasive is a substance that is used for grinding & polishing operations. It should be pure & have uniform physical properties of hardness, toughness, & resistance to fracture to be useful in manufacturing grinding wheel.

Abrasive may be classified in two principal groups.

(i) Natural.
(ii) Artificial or manufactured.

(i) Natural :- The natural abrasives include sandstone or solid quartz, emery, corundum & diamond. (Directly obtained from mines).

(ii) Artificial :- These are manufactured silicon carbide (SiC) & Aluminium oxide (Al_2O_3).

* Bond :- In order to give an effective continuous cutting action, the grains of abrasive should be held together. The material employed for holding this is known as bond. Bonding material & processes are

(a) Vitrified bonding process :-

→ It is made by bonding clay melted to a glass like consistency with abrasive grains. This type of bond gives a wheel good strength as well as porosity to allow high stock removal with cool cutting. This type of bonded wheel denoted by the letter 'V'.

(b) Silicate bonding process :

→ These are made by mixing abrasive grains with silicate of soda or water glass. This is denoted by the letter 'S'.

(c) Shellac bonding process :

→ This bonded wheels are also known as elastic bonded wheels. In this process, the abrasive & shellac are mixed in heated containers & then rolled or pressed in heated moulds. This is denoted by the letter 'E'.

(d) Resinoid bonding process :

→ These wheels are produced by mixing abrasive grains with synthetic resins & other compounds. This is denoted by the letter 'B'.

(e) Rubber bonding process :

→ These wheels are prepared by mixing abrasive grains with pure rubber & sulphur. This is denoted by the letter 'R'.

(F) Oxychloride bonding process :

→ This process consists of mixing abrasive grains with oxide & chloride of magnesium. This is denoted by the letter 'O'.

Grit, Grade & structure of wheels.

(i) Grit : The grain or grit number indicates in a general way the size of the abrasive grains used in making a wheel, or the size of the cutting teeth, since grinding is a true cutting operation.

→ Grain size is denoted by a number indicating the number of meshes per linear inch (25.4mm) of the screen through which the grains pass when they are graded after crushing.

Common Abrasive grain type & size

Grain size or grit.

	Grain size or grit						
(1) coarse	10	12	14	16	20	24	
(2) Medium	30	36	46	54	60		
(3) Fine	80	100	120	150	180		
(4) very fine	220	240	280	320	400	500	600

(ii) Grade : The term grade as applied to a grinding wheel refers to the hardness with which the bond holds the cutting points or abrasive grains in a place. It doesnot refer to the hardness of the abrasive grain.

Grade of grinding wheel.

1. Soft — A B C D E F G H
2. Medium — I J K L M N O P
3. Hard — Q R S T U V W X Y Z.

(iii) Structure :- Abrasive grains are not packed in the wheel but are distributed through the bond. The relative spacing is referred to as the structure & denoted by the number of cutting edges per unit area of wheel face as well as by number & size of of void spaces between grains. It may be "dense" or "open" type.

* open structured wheels are used to grind soft & ductile material.
* Dense structure wheels are used in grinding brittle materials.

Structure of grinding wheels.

Dense : 1 2 3 4 5 6 7 8.

open : 9 10 11 12 13 14 15 or higher.

Standard Marking system :-

→ The indian standard marking system for grinding wheels, has been prepared with a view to establishing a uniform system of marking of grinding wheels to designate their various characteristics, to give a general indication of the hardness & grit size of any wheel as compared with another.

→ Each marking shall consists of six symbols.

① Abrasive type. ② Grain size. ③ Grade. ④ Structure. ⑤ Bond type. ⑥ Manufacturer's record.

sequence :-

Prefix	Abrasive	Grain size	Grade	Structure	Bond type	Suffix
W	A	46	K	5	V	17

Abrasive:
- A = Aluminum oxide.
- C = Silicon carbide.
- D = Diamond.

Grain size:

Coarse	Medium	Fine	Very fine
10	30	80	220
12	36	100	240
14	46	120	280
16	54	150	320
20	60	180	400
24			500
			600

Structure:

Dense	Open
1	9
2	10
3	11
4	12
5	13
6	14
7	15
8	

Bond type:
- V = Vertified
- B = Resinoid
- R = Rubber
- E = Shellac
- S = Silicon
- O = Oxychloride

Grade {A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z}

W & 17 → Manufacture's abrasive type symbol. (use optional)

* **Selection of Grinding wheel:-**

(i) Properties of material to be machined.
(ii) Quality of surface finish required.
(iii) Dimensional accuracy required.
(iv) Method of grinding.
(v) speed & feed of the wheel.
(vi) Type of grinding to be done.

* **Cutting Speed:-** It refers to the peripheral speed of the grinding wheel.

$$V = \frac{\pi D N}{1000} \ m/min.$$

V = Peripheral speed.
D = Diameter of grinding wheel.
N = R.P.M of grinding wheel

* **Feed:-** The feed (f) in cylindrical grinding in the longitudinal movement of the workpiece per revolution.

$$f = C \cdot b \ mm/rev. \text{ of workpiece}$$

The value of "C" for two types of grinding as follows.

Rough grinding → 0.6 to 0.9
Finish grinding → 0.4 to 0.6.

when b = the width of the face of the grinding wheel.
C = a constant, depending upon the type of grinding being done.
i.e. rough grinding or finish grinding.

$$\text{Work travel or Table Travel} = \frac{f \times N}{1000} \text{ m/min}$$

f = feed in mm/rev.

N = rpm of the workpiece.

* Depth of cut (t): It represents the thickness of the metal removed by the grinding wheel in one pass or one longitudinal traverse.

It is given by.

$$t = \frac{D_1 - D_2}{2} \text{ mm.}$$

t = depth of cut.

D_1 = workpiece diameter before grinding.

D_2 = workpiece diameter after grinding.

The normal depth of cut in grinding varies from 0.005 mm to 0.04 mm, depending upon the type of grinding, work material, bond, etc.

The common ranges are.

For finish grinding = 0.005 mm to 0.015 mm.

For Rough grinding > 0.015 mm.

Machining time (T)

$$T = \frac{L \cdot P \cdot K}{f \cdot N \cdot t} \text{ min.}$$

where
L = longitudinal travel in one pass (mm)

P = Number of passes made.

f = longitudinal feed/rev. (mm)

N = r.p.m of the workpiece.

K = a constant (Accuracy factor), depending upon the degree of accuracy & level of surface finish.

1.0 to 1.2 → for Rough grinding. (Commonly used value = 1.1)

1.3 to 1.7 → for Finish grinding. (Commonly used value = 1.4)

t = depth of cut.

* Indexing Mechanism :-

→ Indexing can be defined as the operation to divide (index) the circular periphery of the workpiece into equal number of division. It may be performed for unequal number of division. This is performed with the aid of indexing of dividing head attached on the milling machine.

→ Indexing heads are three types :-

(a) plain dividing head.
(b) universal dividing head.
(c) optical dividing head.

(a) Plain dividing head :-

These can be broadly classified into two types.

Type (i) Plain dividing head carrying index plate without worm & worm wheel.
~~(in addition to index plate)~~

Type (ii) plain dividing head with worm & worm wheel (in addition to index plate)

Type (i)

→ It is the simplest among all dividing heads. It is used in direct indexing. This type of index plate is mounted directly on the spindle of the ~~dividing~~ dividing head. There is no worm & worm wheel. The work piece is held in between two centres (as in lathes), one on the tailstock centre & other on dividing head spindle.

→ The dividing head spindle may carry carrier or dog. The spindle can be locked with the help of the hand lever (such arrangement is also provided in lathe for locking the tailstock centre).

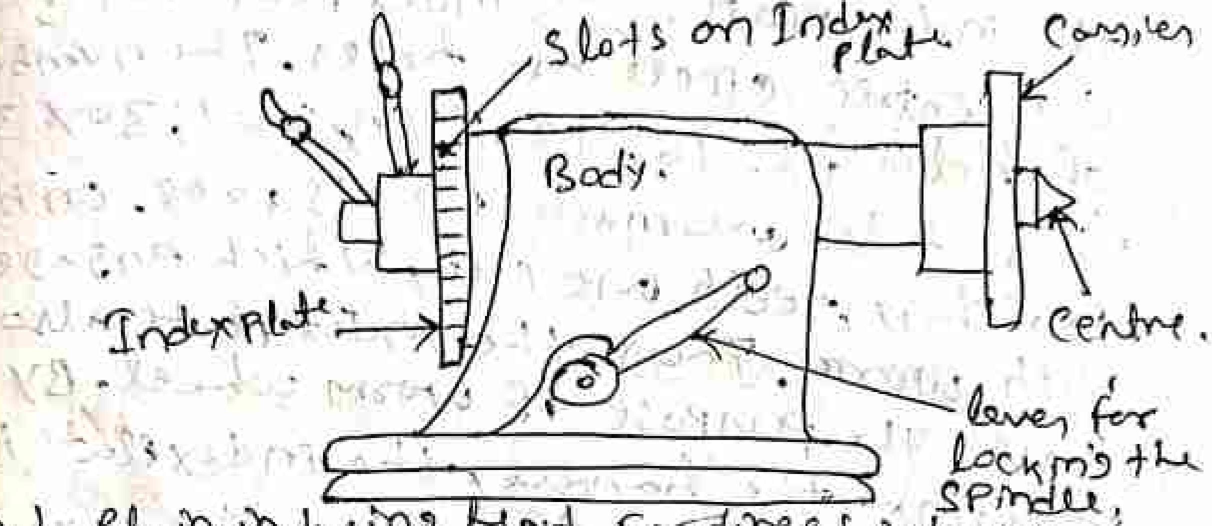


fig-1 Plain indexing head for direct indexing.

→ The index plate can have 12 or 24 slots (equispaced) on its periphery.
with 12 slots, plate following divisions are available - 2, 3, 4, 6 & 12.
plate with 24 slots gives - 2, 3, 4, 6, 8, 12 & 24 division.

→ The spindle & the plate together can be rotated with the help of a handle on the left side of the dividing head. For giving desired rotation to the workpiece, number of slots is decided (which would provide the rotation) & a lug is used to engage that slot.

Type-(ii) :

→ A body carries a spindle of which on one end (front end) is mounted a carrier & a centre, on the other end (rear) is mounted the index plate. The index plate has 3 concentric circle of holes. The number of holes is, 16, 42 & 60 or 24, 30 & 36. These holes are made on its face. On its periphery, teeth are cut, which engage with worm. Thus the index plate also serves the purpose of worm wheel. By rotating the handle, the index plate is rotated through the worm. A crank carrying a pin is mounted on a bolt. It can be swivelled to any degree to fit the pin in the desired hole.

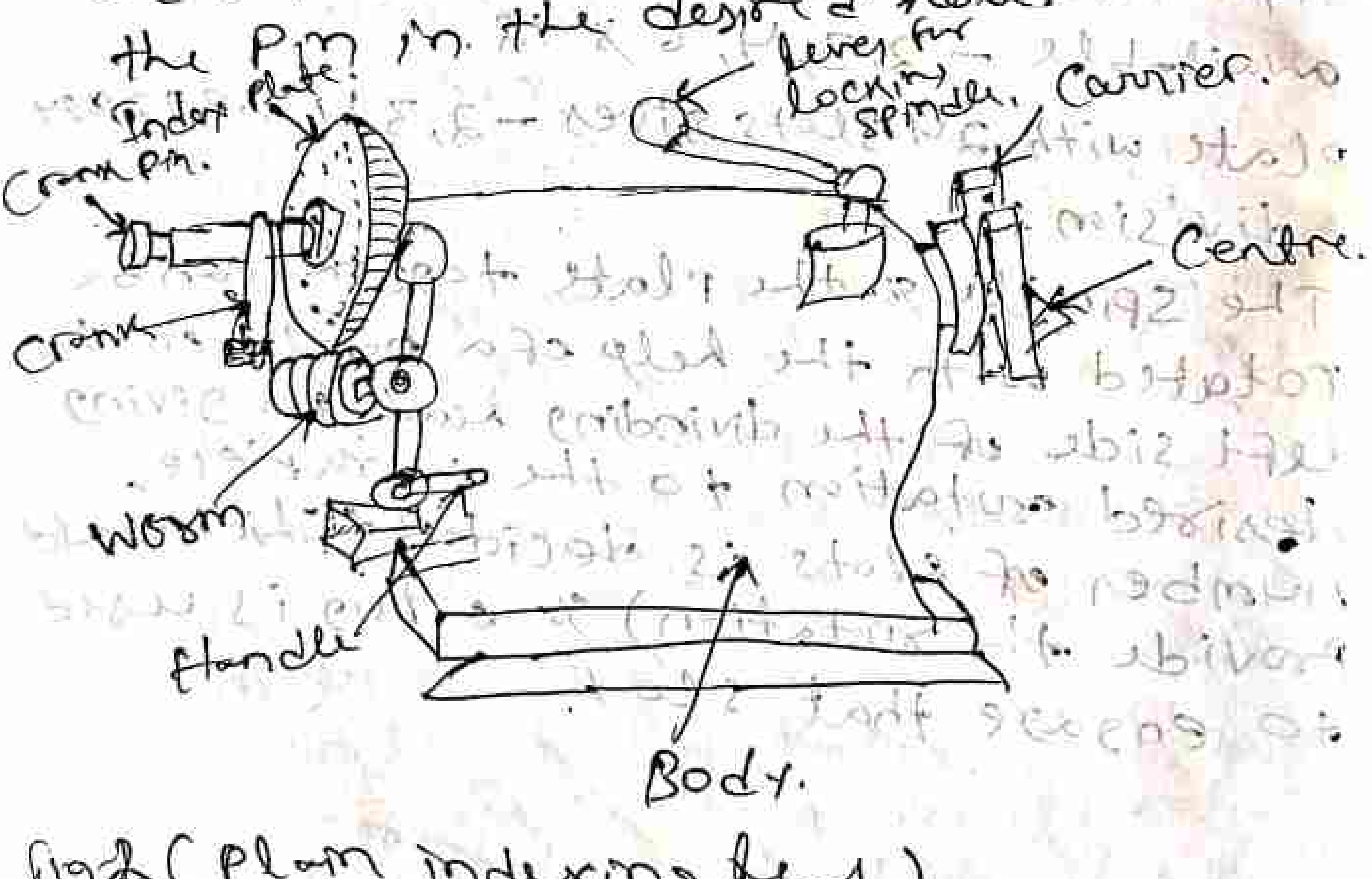


fig-2 (plain indexing head)

(b) Universal dividing head :-

→ The universal dividing head is a widely used & accurate indexing attachment which may be even used to support the workpiece between the centers or hold it in a chuck. It incorporates :

(1) Indexing arrangement, &

(2) Gears, which are connected to the driving mechanism; so that the workpiece could be given.

It also accomplish the following functions.

(i) It acts as both supporting & holding device for the workpiece with the help of tail stock.

(ii) It sets the workpiece at any given angle to the horizontal axis or machine table.

(iii) It turns the work through any given angle or division after each cut (on the work) on the periphery of the workpiece i.e it indexes the periphery of the workpiece after each operation (or cut).

(iv) It provides a continuous rotary motion to the work in a predetermined relation to the motion of the milling machine table.

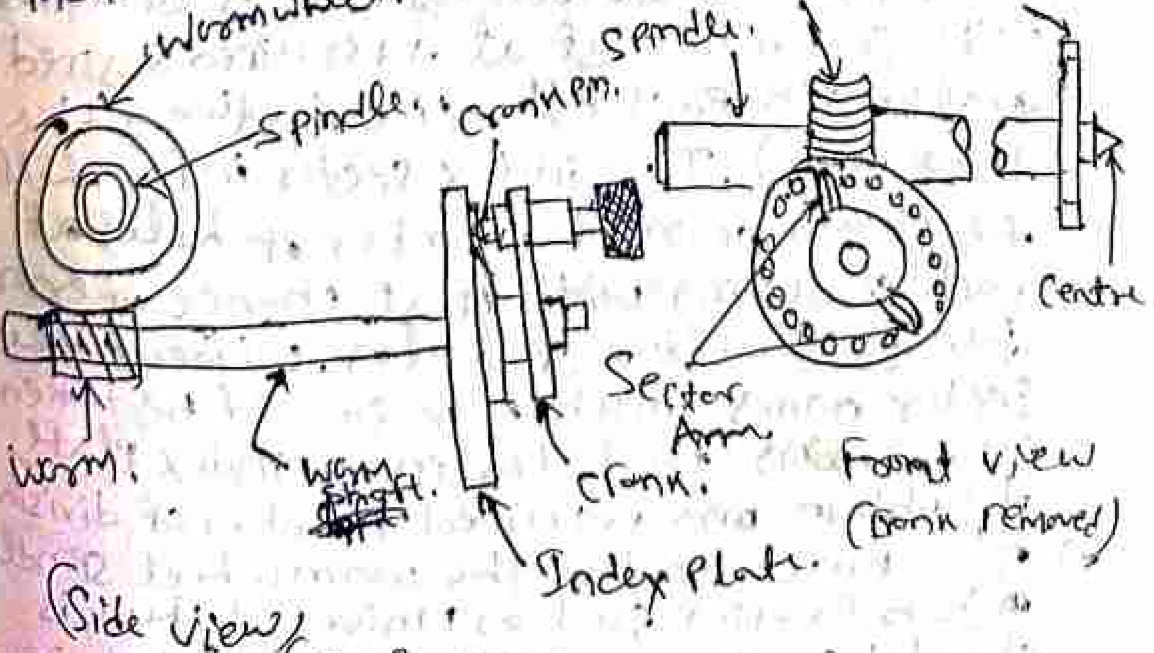


Fig-3

→ The dividing head spindle carries the worm wheel (having 40 teeth). This worm wheel meshes with the worm (with single start thread). The worm shaft (at right angles with the worm wheel shaft) carries a crank (or index crank) at the other end.

→ The index plate is on a sleeve, which is mounted over the worm shaft. Thus as the worm rotates, the crank rotates but not the index plate. That why is the index plate can move independent of the rotation of the worm shaft & also rotation of the crank.

→ The index pin is housed in a plunger that is spring loaded. A radial slot is cut in the crank through which the plunger can slide to adjust the pin position for fitting into holes of different concentric circles. (Since different circles are at different radial distances from the centre of the index plate, & there are more than one circle in each plate)

→ The sector arms are provided on the index plate. These are usually of detachable type & can be set at a required desired angle with each other (i.e. between the two arms). The index sector in fact helps to obtain correct number of holes at each indexing with least chance of error due to counting of holes. Without the sector arms much care should be taken in counting the holes in an index plate, to obtain any required number of divisions.

→ The front end of the worm wheel spindle a job carrier such as universal chuck is threaded & a 60° centre may be inserted in the spindle.

→ A tailstock is used in conduction with the headstock to support the workpiece held in between the centres or the end of the work may be held in a chuck. The tailstock can be adjusted longitudinally to accomdate various lengths of job. It may even be raised or lowered off centre. It may even be tilted out of parallel with the base when machining are being performed on tapered work. The spindle carries the worm wheel also carries a set of change gears on the back side of the dividing head.

© Optical dividing head :

→ The optical dividing heads are used for precise angular indexing during machining, & for checking the accuracy of various angular surfaces.

→ The mechanism comprises a worm gear which is keyed to the spindle & may be rotated by a worm. A circular glass scale graduated in 1° division is rigidly mounted on the worm wheel.

→ Any movement of the spindle effected by rotating the worm is read off by means of a microscope fitted on the dividing head body. The reading on the circular glass scale is projected through prisms on the screen of the microscope eyepiece. The eyepiece has a scale 60 divisions & each division is equivalent to 1° movement of the circular scale. Thus with this arrangement, a precise indexing movement can be made.

* Indexing method :

→ By indexing we mean division of the job periphery into a desired number of equal divisions. It is accomplished by a controlling movement of the crank such that the job rotates through a definite angle after each cut is over. The following methods of indexing are commonly used :

(i) Direct indexing (ii) plain or simple indexing

(iii) Compound indexing (iv) Differential indexing.

(i) Direct indexing :

→ It is the simplest case of indexing in which a plain dividing head (Fig.) as indicated there, the index plate is directly mounted on the spindle & rotated by hand. It can be used only when the number of divisions to be obtained is such that the number of slots on the periphery of the index plate is a multiple of the former. The indexing ratio is obtained by:

$$\text{Required ratio} = \frac{N}{n}$$

(It can be used for producing 2, 3, 4, 6, 8, 12)

where N = No. of slots on the periphery of the index plate.

n = No. of divisions required to be obtained

For example, if the circumference of a job has to be divided into 6 equal divisions & the index plate has 24 slots, the required ratio will be $= \frac{24}{6} = \frac{4}{1}$ i.e i.e the index plate will be required to move through 4 slots after each cut is over.

Alternatively, the the plain indexing head can also be used for direct indexing fig-2, for this the worm will have to be kept out of mesh with the worm wheel & the ratio is obtained in the same way as above.

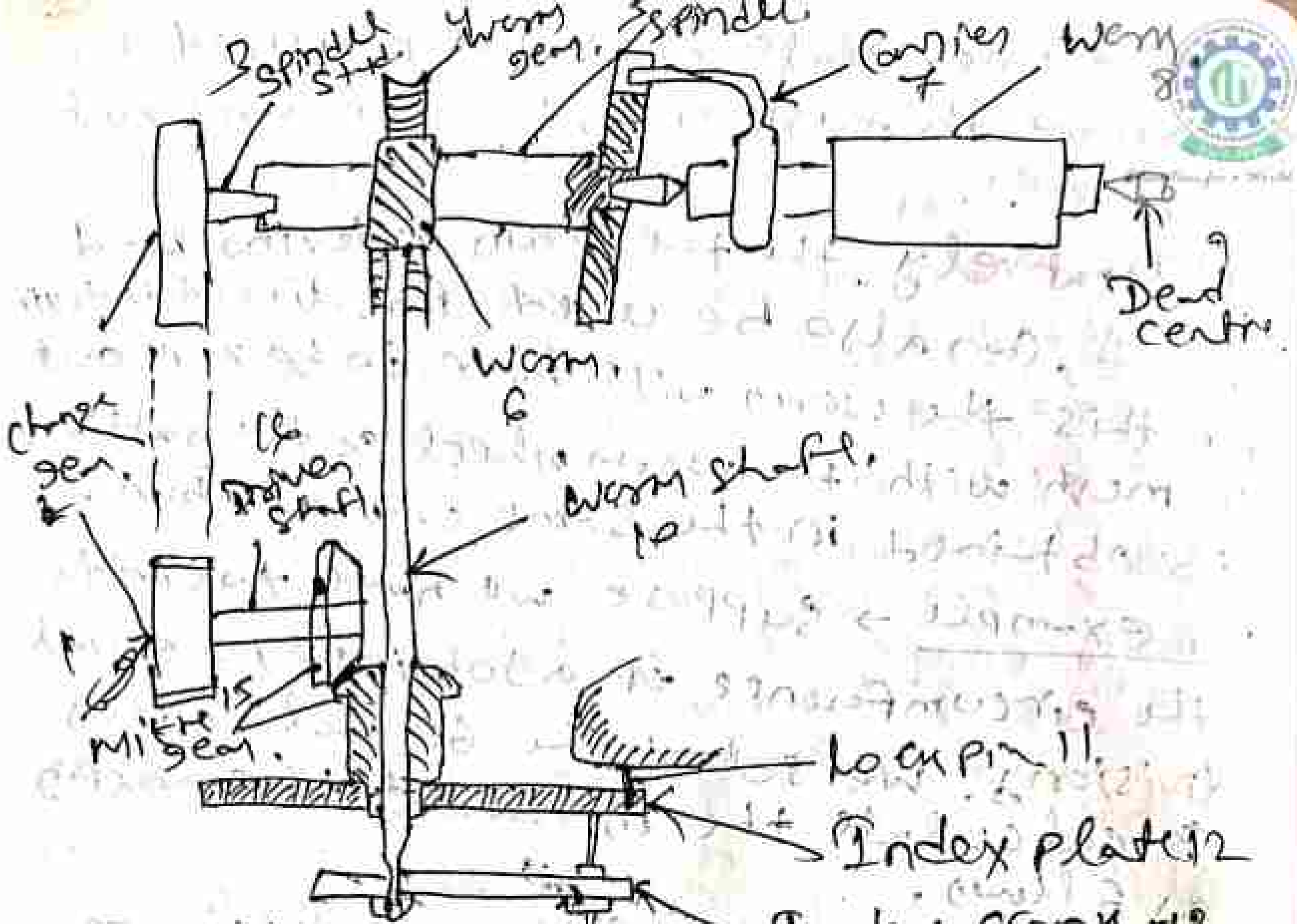
For example → suppose we have to divide the circumference of a job into 10 equal divisions. We select the 60 holes circles & calculate the movement of crankpin as follows.

The required movement = $\frac{60}{10}$ = 6 division on 60 holes circle

(ii) Plain or simple indexing.

→ This method of indexing is used when the direct method of indexing cannot be employed for obtaining the required number of divisions on the work.

For example, if the work is required to be divided into 22 equal divisions the direct indexing can not be used, because 22 is not divisible into any of the hole circles on the direct indexing plate. For such cases, simple indexing can easily be used.



(Fig-4) (universal dividing head)

→ It is more accurate & suitable for numbers beyond the range of rapid indexing. Here the dividing head spindle is moved by turning the index crank. As the worm shaft carrying the crank has a single threaded worm (6) which meshes with the worm gear having 40 teeth.

→ 40 turns of the crank are necessary to rotate the index head spindle through one revolution. In other word one complete turn of the index crank will cause the worm wheel to make 1/40 of a revolution.

Index crank movement = $\frac{40}{N}$.

N → No. of division required.

Example → Set the dividing head to mill 30 teeth on a spur wheel blank.

Index crank Movement = $\frac{40}{30} = 4/3 = 1\frac{1}{3} \times \frac{7}{7}$

$= 1\frac{7}{21}$

Thus for indexing, one complete turn & 7 holes in 21 hole circle of the index plate will have to be moved by the index crank.

Index plates with circles of holes patented by Brown & Sharp Manufacturing Company are as Follows.

Plate No-1 – 15, 16, 17, 18, 19, 20

Plate No-2 – 21, 23, 27, 29, 31, 33

Plate No-3 – 37, 39, 41, 43, 47, 49.

(iii) Compound indexing. Fig. 4

→ The indexing method is called compound indexing due to the two seperate movements of the index crank in two different hole circles of one index plate to obtain a crank movement not obtainable by plain indexing. The index plate is normally held stationary by a lock pin which engages with one of the hole circles of the index plate from the back.

→ While indexing, first the crank pin is rotated through a required number of spaces in one of the hole circle of the index plate & then the crank pin is engaged with the plate. The first movement is performed similar to the plain indexing. The second index movement is now performed by removing the rear lock pin & then rotating the plate together with the index crank forward or backward through the calculated number of spaces of another hole circle & the the lock pin is engaged.

→ The effective indexing movement will be summation of the two movements. The method of findinding the index crank movement being a complicated one & is seldom used now adays.

Rules for compound indexing.

$$\frac{40}{N} = \frac{n_1}{N_1} \pm \frac{n_2}{N_2}$$

where

$N \rightarrow$ Number of division required.

$N_1 \rightarrow$ The hole circle used by the crank pin.

$N_2 \rightarrow$ the hole circle used by the lock pin.

$n_1 \rightarrow$ The hole space moved by the crank pin in N_1 hole circle.

$n_2 \rightarrow$ the hole spaces moved by the plate & the crank pin in N_2 hole circle.

Procedure for determining the index circles.

① Resolve into factors the number of divisions required.

② choose at random hole circle.

③ Subtract the hole number of one circle from the other.

④ Factor the difference.

⑤ Place the factors of the divisions required & the factors of the difference above a horizontal line.

⑥ Next Factor the number of turns of the crank required for one revolution of the spindle (40), & also factor thee hole circles chosen.

7) place these three new factors below the horizontal line.

8) Cancel the common factors above & below the line. If all the factors above the line can be cancelled by those placed below, then the two circles chosen can be used for indexing. If the factors above the line cannot be completely cancelled then the other hole circles should be chosen for trial calculation.

9) The factors which will remain uncancelled below the line, should be multiplied to obtain the space in the hole circle to be moved by the two indexing movements.

Example -

Index 69 division by compound indexing.

$$\frac{40}{69} = \frac{n_1}{N_1} \pm \frac{n_2}{N_2}$$

1) $69 = 23 \times 3$ — n_2 of 10.

2) Index circle 23 & 33 are chosen.

3) $33 - 23 = 10$

4) $10 = 2 \times 5$

(5) $69 = 23 \times 3$ & $10 = 2 \times 5$ → put Above horizontal line

(6) $40 = 2 \times 2 \times 2 \times 5$, $23 = 23 \times 1$ & $33 = 3 \times 11$ → put below the horizontal line.

(7,8)
$$\frac{\cancel{23} \times \cancel{3} \times \cancel{2} \times \cancel{5}}{2 \times 2 \times \cancel{2} \times \cancel{5} \times \cancel{23} \times 1 \times \cancel{3} \times 11}$$

All the taking above line are cancel, hence circle 23 & 33 can be used for indexing.

Thus $N_1 = 23$ & $N_2 = 33$.

(9) The factor which remain uncancelled below the line.

$2 \times 2 \times 11 \times 1 = 44$

therefore 44 is the number of holes moved for indexing.

Trial & error method

$$\frac{40}{69} \Rightarrow \frac{44}{23} + \frac{44^{4}}{\cancel{33}_{3}} = \frac{44}{23} + \frac{4}{3} = \frac{44 \times 3 + 23 \times 4}{69} = \frac{132 + 92}{69} = \frac{224}{69} \times$$

$$\frac{40}{69} \Rightarrow \frac{44}{23} - \frac{44^{4}}{\cancel{33}_{3}} = \frac{44}{23} - \frac{4}{3} = \frac{132 - 92}{69} = \frac{40}{69} \checkmark$$

$$\frac{40}{69} = \frac{44}{23} - \frac{44}{33}$$

remainder

$$= 1\frac{21}{23} - 1\frac{11}{33}$$

cocent ↗ divider.

$$= \frac{21}{23} - \frac{11}{33}$$

∴ Therefore for indexing 69 division, the index crank should be move the index crank by 21 holes in 23 hole circle in forward direction (because its +ve) the crank together is moved by 11 holes in 33 hole circle in the backword direction (because its -ve)

(iv) Differential indexing →

→ The indexing method is called differential because the required division is obtained by combination of two movements.

(a) The movement of the index crank similar to the simple indexing.

(b) The simultaneous movement of the index plate, when the crank is turned

→ The rotation or differential motion of the index plate may take place in the same direction as the crank or opposite to it as may be required. The result is that the actual movement of the crank at every indexing is automatically increased or decreased giving the required index movement of the spindle. for this reason, the differential indexing may be considered as an automatic method of performing compound indexing.

→ In Fig 4 while differential indexing, the lock pin is disengaged with the index plate which is screwed to a sleeve. A mitre gear is fastened to the other end of the sleeve. The index plate, the sleeve & the mitre gear are free to rotate on the worm shaft. The mitre gear meshes with another mitre gear on shaft. The tail end of the spindle hold a stud.

→ The change gear may be mounted betn the stud & shaft. The gear on the spindle is driving gear & the gear on the shaft is driven gear. The change gear train may be simple or compound. Now with this gearing arrangement, as the index crank is turned, rotating the spindle, the index plate is slowly rotated in one direction or the other, depending upon the gearing.

→ Thus the differential movement of the crank relative to the plate is obtained. The total movement of the crank is equal to its movement relative to the plate plus the movement of the plate. The movement of the index plate may be added or subtracted according to the direction of rotation of the plate

Differential index ing heads are generally furnished with change gears as follows

— 24, 28, 32, 40, 44, 48, 56, 64, 72, 86, 100

with these change gears & three sets of standard index plate (B & S), it is possible to index any number from 1 to 382.

Special gears having 46, 47, 52, 58, 68, 70, 76 & 84 teeth may also be furnished for numbers from 383 to 1008 divisions.

Rule for differential indexing:

The following are the different rules for determining gear ratio, indexing movement of the crank & the number of idlers required.

① Gear ratio = $\frac{(A-N) \times 40}{A}$ — ①

where A = the selected number which can be indexed by plain indexing & the number is approximately equal to N,

N = the required number of divisions to be indexed.

② In the gearing ratio so calculated the numerators of the fraction indicate the driving gears on the index head spindle & the denominator indicate the driven gears on the index plate.

③ Index crank movement = $\frac{40}{A}$ — ②

where A is the selected number.
The index crank will have to be moved by an amount given in the formula (1) for N number of times for complete division of work.

(4) The Index crank & the index plate should move in the same direction or opposite to each other depending on the type of gearing ratio & the selected number 'A' choosen.

If (A-N) is positive index plate must rotate in the same direction as the crank & if (A-N) is negative index plate must rotate in direction opposite to that of the crank.

To achieve these conditions, the number of idle gears used depends upon the following factors.

(a) If the gear train is simple & (A-N) is positive, only one idle gear is used.
(b) If the gear train is compound & (A-N) is positive, No idle gear is used.
(c) If the gear train is simple & (A-N) is Negative, two idle gears are used.
(d) If the gear train is compound & (A-N) is negative, only one idle gear is used.

Example: Index 83 division.

First of all, find out whether the number can be indexed by simple or plain indexing or not.

Index crank movement in plain indexing $= \frac{40}{N}$

$= \frac{40}{83}$

Since there is no 83 hole circle, the number cannot be indexed by plain indexing. Therefore, it is a case of differential indexing.

Assume $A = 86$, a number almost equal to 83 can be indexed by plain indexing.

① Gear ratio $= (A - N) \times \frac{40}{A}$

$= (86 - 83) \times \frac{40}{86}$

$= 3 \times \frac{40}{86}$

$= \left(3 \times \frac{24}{24}\right) \times \frac{40}{86}$

$= \frac{72}{24} \times \frac{40}{86}$

② Therefore, Drivers $= 72, 40$

Driven $= 24, 86$

③ Index crank movement $= \frac{40}{86} = \frac{20}{43}$

→ For complete indexing, the index crank will have to be moved by 20 holes in 43 hole circle for 83 times.

(4) As (A-N) is positive & the gearing ratio is compound, no idle gear is required.

MODULE-III

Non traditional machining processes

Need for NTM

→ Intricate-shape can be machined.

→ Difficult to machine material.

→ Deep hole with small hole diameter.

Classification of NTM Process :-

Depending upon the nature of energy used.

* Mechanical Processes :-

→ Abrasive Jet machining. (AJM)

→ Ultrasonic Machining (USM)

→ Water Jet machining (WJM)

→ Abrasive water Jet machining (AWJM)

* Electrochemical processes :-

→ Electro chemical Machining. (ECM)

→ Electro chemical Grinding (ECG)

→ Electro Jet drilling (EJD)

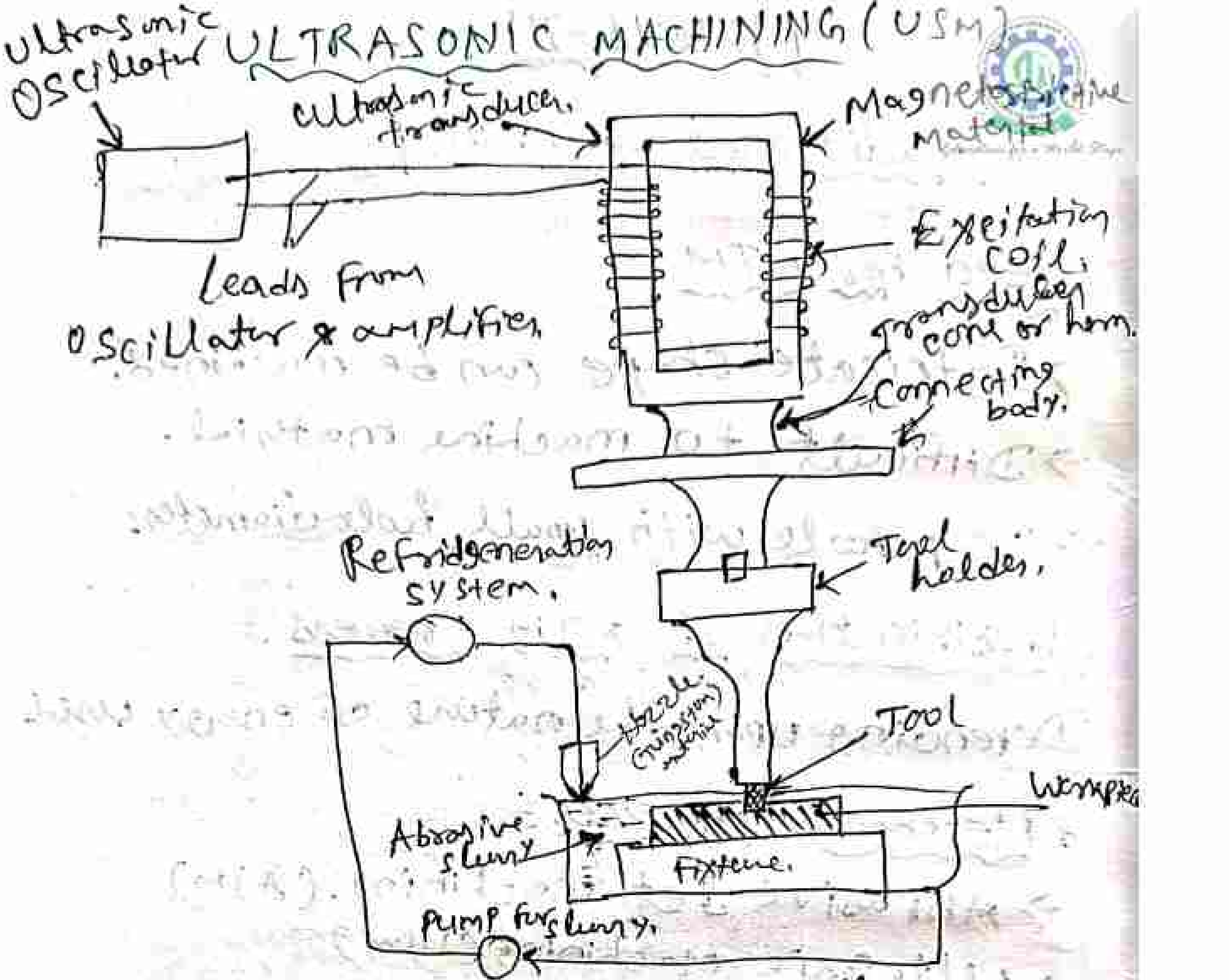
* Electro Thermal Processes.

→ Electro discharge machining (EDM)

→ Laser Beam Machining (LBM)

→ Electron Beam machining (EBM)

ULTRASONIC MACHINING (USM)



→ In this machining method, a slurry of small abrasive particles is forced against the work by means of a vibrating tool, removing the workpiece material in the form of extremely small chips.

→ The grains used are of silicon carbide, aluminium oxide, boron carbide or diamond dust. This process is suitable only for hard & brittle material like carbides, glass, ceramics, silicon, germanium, titanium, tungsten, tool steel, die steels.

→ The vibrating frequency used for the tool is of the order of over 20,000 oscillations per second. An electro mechanical transducer is used for producing this high frequency of vibration

→ The tool is made of relatively soft metal. It is applied to the workpiece surface & the slurry applied either manually or through a pump.

→ The main advantage of this process is that the workpiece after being machined is normally free from residual mechanical stresses & a high degree of surface finish can be obtained.

→ The metal in this process is facilitated by the abrasive action of each grain which is hammered by the high frequency oscillating tool into the work material. That is why this process is also known as impact grinding or ultrasonic grinding.

→ In this operation, a high frequency electric current is sent by the ultrasonic oscillator to the ultrasonic transducer. The function of the transducer is to convert this electric energy into mechanical vibrations. The vibrations so generated are of the order of 20KHz to 30KHz, although the available amplitude usually varies from 0.01mm to 0.1mm.

→ The transducer is made of a magneto-strictive material, which is excited by the flowing high frequency electric current & this result in the generation of mechanical vibrations.

→ These vibrations are then transmitted to the cutting tool via the intermediate connecting parts, such as transducer, cone or horn, connecting body, & tool holder.

→ The shape of the cutting tool is the same as that of the cavity to be produced by it.

Advantages of USM:

(i) Extremely hard & brittle material can be easily machined.
(ii) Highly accurate profiles & good surface finish can be easily obtained.
(iii) The machined work pieces are free of stresses.
(iv) Metal removal cost is low.
(v) The operation is noiseless.
(vi) Operation of the equipment is quite safe.

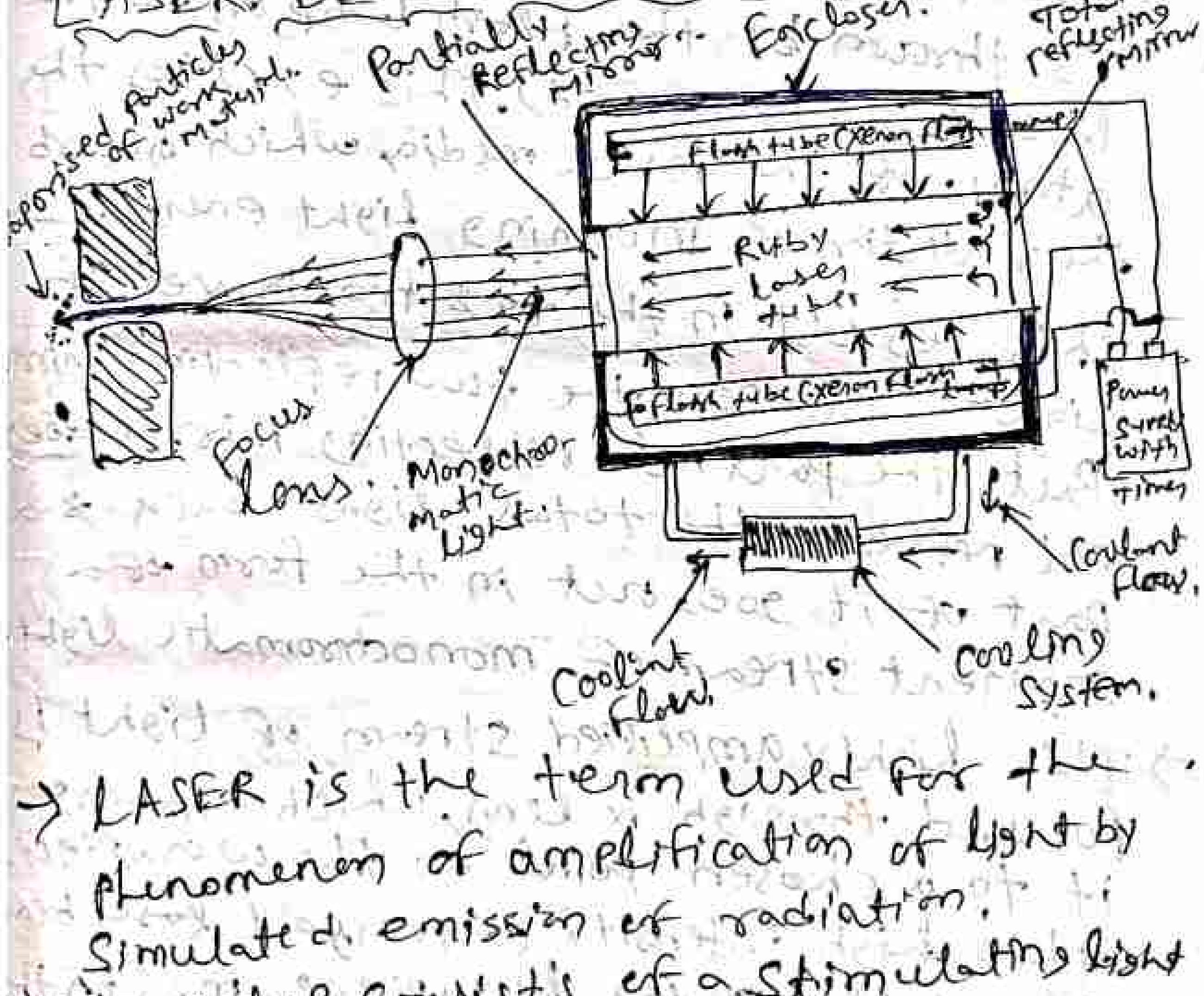
Disadvantage of USM:

(i) The MRR is low.
(ii) The initial equipment cost is higher than the conventional machine tools.
(iii) The process does not suit to heavy metal removal.
(iv) Power consumption is quite high.
(v) The size of cavity that can be machined is limited.
(vi) In order to maintain an efficient cutting action the slurry may have to be replaced periodically

Application of USM

(i) Tool & die making.
(ii) Machining of hard to machine & brittle material.
(iii) producing holes of round or such other shapes which can be provided to the cutting tool.

LASER BEAM MACHINING (LBM)



→ LASER is the term used for the phenomenon of amplification of light by simulated emission of radiation.

→ The setup consist's of a stimulating light source (like xenon flash lamp) & a laser rod. The light radiated from the flash lamp is focused on to the laser tube (laser rod), from where it is reflected & accelerated in the path. This light is emitted in the form of a slightly divergent beam.

→ A lens is incorporated suitably in the path of this beam of light which converges & focused the light beam on to the workpiece to be machined.

→ This concentration of laser beam on the workpiece melts the work material & vaporises it.

→ In operation, the optical energy (light) is thrown by the flash lamp on to the laser tube (Ruby rod). This excites the atoms of the inside media, which absorb the radiation of incoming light energy.

→ This result in the to & fro travel of light between the two reflecting mirrors. But, the partial reflecting mirror does not reflect the total light back & a part of it goes out in the form of a coherent stream of monochromatic light.

→ This highly amplified stream of light is focused through a lens, which converges it to a chosen point on the workpiece. This high intensity converged laser beam when falls on the workpiece, melts the workpiece material, vaporises it almost instantaneously & penetrates into it. Thus it can be called a type of thermo cutting process.

* Advantages of LBM :-

(i) Any material can be easily machined irrespective of its structure, & physical & mechanical properties.

(ii) Unlike conventional machining, there is no contact between the tool & the workpiece & no involvement of large scale cutting forces.

(iii) Can be effectively used for welding of dissimilar metals as well.

(iv) Small heat effected zone around the machine surface.

(v) Very small holes & cuts can be made with fairly high degree of accuracy.

* Disadvantage of LBM :-

(i) High capital investment needed.

(ii) Operating cost is also quite high.

(iii) Highly skilled operator requires.

(iv) Production rate is low.

(v) Its application is limited to only thin sections & where a very small amount of metal removal is involved.

(vi) Can not be effectively used to machine highly heat conductive & reflective material.

* Application of LBM :-

(i) Drilling small holes in hard materials like tungsten & ceramics.

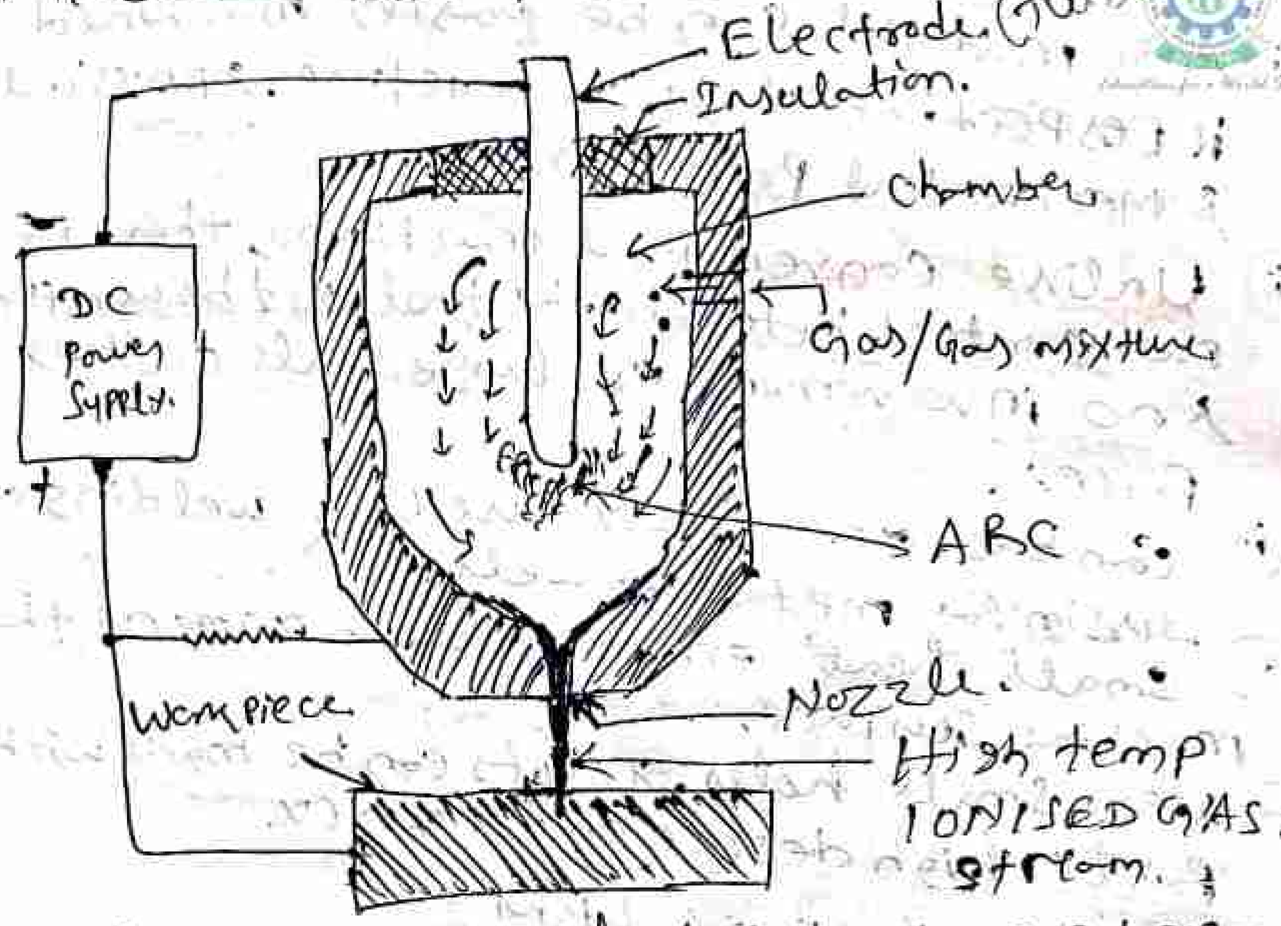
(ii) Cutting complex profiles on thin & hard material.

(iii) Cutting or engraving patterns on thin films.

(iv) Dynamic balancing of precision rotating components such as watches.

(v) Trimming of sheet metal & plastic parts.

* PLASMA ARC MACHINING :-



→ When gases are heated to temp. above 5500°C, they are partially ionised & exist in the form of a mixture of free electrons, positively charged ions & neutral atoms, This mixture is termed as plasma.

→ The temp. of central part of plasma goes as high as between 11000°C to 28000°C, where the gas is completely ionised.

→ In plasma arc machining, a high velocity jet of this high temp. ionised gas is directed on to the workpiece surface by means of a well designed plasma arc cutting torch. This jet melts the metal of the workpiece & displaces the molten metal away from its path.

→ The heating of workpiece material is not due to any chemical reaction but on account of the continuous attack of electrons which transfer the heat energy of high temp. ionised gas to the work material. This process can, therefore, be safely used for machining of any metal, including those which can be subjected to chemical reaction.

→ The plasma cutting torch carries a <u>tungsten electrode</u> fitted in a small chamber. This electrode is connected to the negative terminal of a d.c. power supply source & therefore, act as a cathode. The other (+ve) terminal of the power supply is connected to the nozzle formed near the bottom of the chamber. The nozzle acts as an anode. On one side of the torch is provided a passage for supply of gas into the chamber. There is also a provision of water circulation around the torch so that the electrode & the nozzle both remain water cooled.

→ A strong arc is struck between the electrode (cathode) & the nozzle (anode) & the gas forced into the chamber. As the gas molecules collide with the high velocity electrons of the arc the former get ionised & a very large amount of heat energy is evolved.

→ The flow of gas is so controlled that the arc remains stable. The high velocity stream of hot ionised gas, called plasma, is directed on to the workpiece to melt its material & also blow it away.

→ The mechanism of material removal is based on:
(i) heating & melting.
(ii) Removal of the molten metal by the blasting action of the plasma jet.

Process Parameters :-

Velocity of Plasma Jet - 500 m/s or more

material removal rate - 150 cm³/min.

Voltage - (50-400) V D.C.

Current - (200-1000) A.

Cutting Speed - (0.1 - 7.5) m/min.

max. plate thickness - 200 mm.

* Advantage of PAM

(i) It is equally effective on any electrically conductive material regardless of it's hardness.

(ii) It does not directly contact the workpiece.

(iii) It does not require any special surface preparation.

* Disadvantage of PAM.

(i) Low accuracy.

(ii) Heat affected zone.

(iii) This process are the metallurgical change of the surface.

(iv) Safety precautions are necessary for the operator & those in near by area.

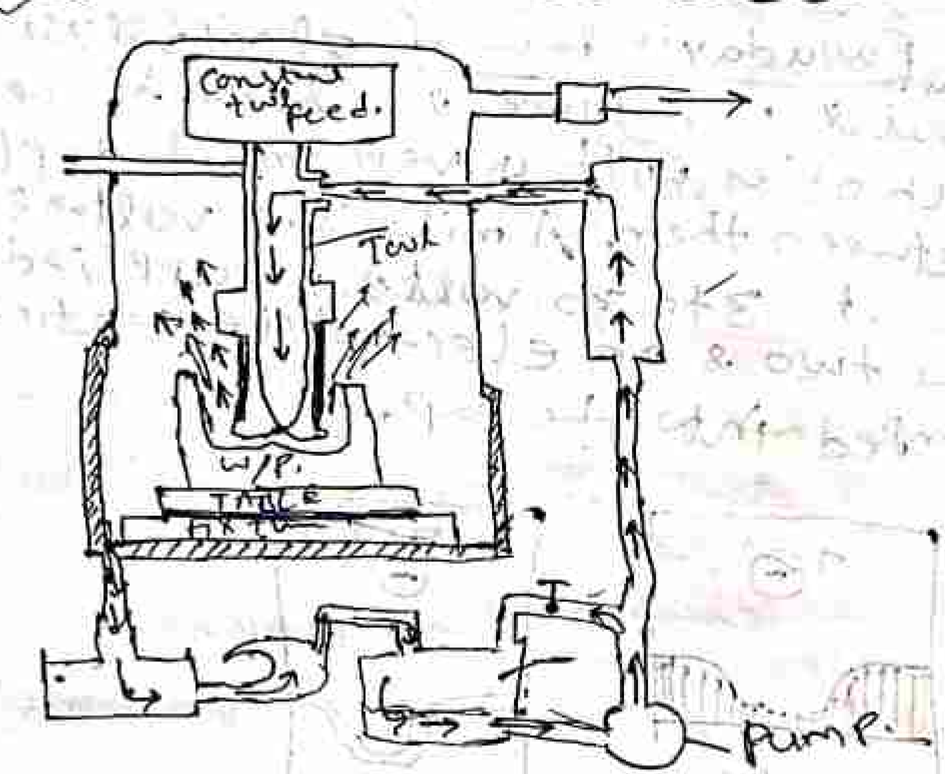
* Application of PAM.

(i) this is chiefly used to cut stainless steel & aluminium alloys.

(ii) It is used to machine the material plates which are difficult to machine by conventional method such as milling etc.

(iii) Profile cutting of metals, particularly of those metals & alloys, has been the most prominent commercial application of PAM.

* Electro chemical machining.



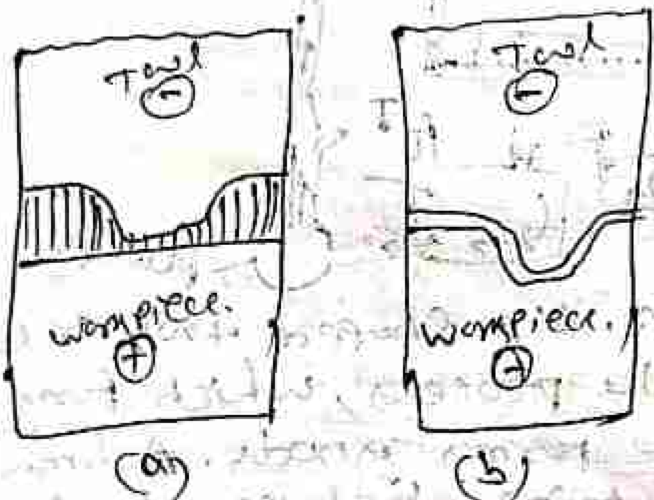
→ In this process a shaped tool or electrode is used in the process, which form cathode. The workpiece forms anode. A small gap is maintained between tool & w/p. & an electrolyte is pumbed through it.

→ Low voltage direct current is employed which, in the presence of electrolyte, enables a controlled removal of metal from the workpiece by anodic dissolution.

→ Most widely used electrolyte in the process is sodium nitrate solution.

→ This process can be successfully used for machining extremely hard metals & alloys, deep holes, small size & odd shape holes, etching process work, etc. The tool used in this process should be made of such materials which have enough thermal & electrical conductivity, high chemical resistance to electrolyte & adequate stiffness & machinability.

→ The principle of ECM process is based on Faraday's law of electrolysis. The tool & workpiece are held close to each other with a very small gap (say 0.5mm between them. A mild D.C voltage of about 3 to 30 volts is applied between the two & an electrolyte continuously pumped into the gap.



Principle of ECM process.
(a) Shape of workpiece before machining.
(b) Tool shape is reproduced on workpiece after ECM.

→ Due to applied voltage current flows through the electrolyte with +ve charged ions being attracted towards the tool (cathode) & the -ve charged ions towards the workpiece (anode). The electrochemical reaction taking place due to this flow of ions results in the removal of metal from the workpiece in the form of sludge.

→ This sludge is taken away from the gap by the flowing electrolyte along it.

* Advantages of ECM :-

1. Any good electrically conducting material can be machined. ~~& its mechanical properties have no bearing.~~
2. Intricate & complex shapes can be machined.
3. MRR is quite high in comparison to conventional machining.
4. No cutting force are involved.
5. High surface finish.

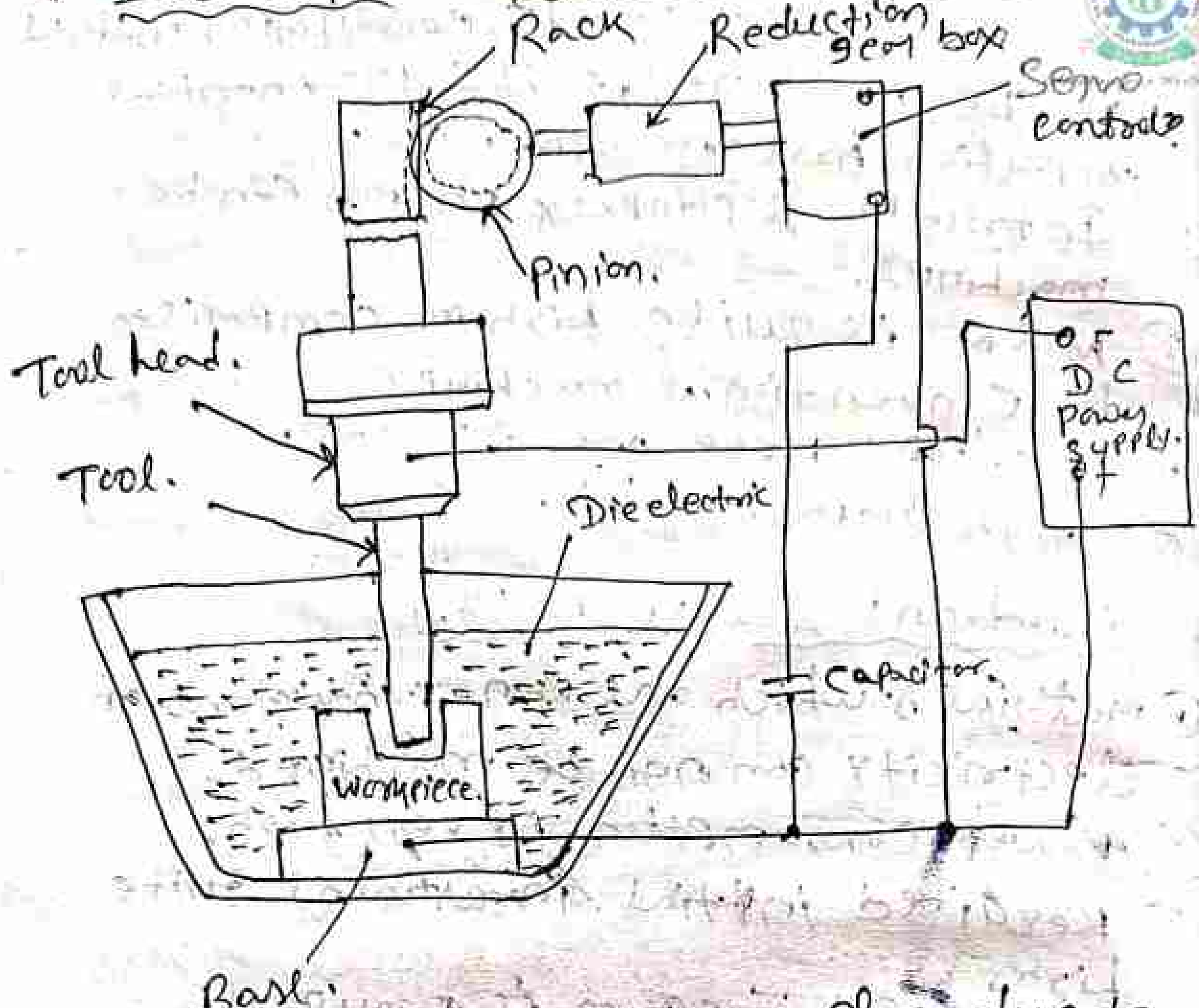
Disadvantages of ECM :-

1. Materials which are non-conductors of electricity can not be machined.
2. Power consumption is very high.
3. Required initial investment quite high.
4. Larger floor space is required.

* Application of ECM.

1. Machining of hard to machine & heat resistance material.
2. Machining of blind holes & pockets, such as forging dies.
3. Machining of complicated profiles, such as of jet engine blades, turbine blades, turbine wheels etc.
4. Drilling small deep holes such as in nozzles.
5. Machining of cavities & holes of irregular shapes.
6.

* Electrical Discharge Machining



→ The metal removal takes place due to erosion caused by the electric spark. This process may be used for machining any material, irrespective of its hardness, which is an electrical conductor. The rate of metal removal & the resulting surface finish can be controlled by proper variation in the energy & the duration of spark discharge.

→ A liquid dieelectric, like paraffin or some light oil, like transformer oil, or kerosene oil, is always used in the process.

→ The main ~~element~~ principle involved in the process is that the workpiece & the electrode (tool) are seperated by a gap, called spark gap. This gap filled up by the dielectric, which breaks down when a proper voltage is applied between these two. The spark gap usually varies from 0.005 mm to 0.05mm. when a circuit voltage of 50V to 450 V is applied, electrons start flowing from the cathode, due to the electrostatic field, and the gap is ionised.

→ The constant drop in resistance & discharge of electric energy results in an electrical breakdown. The electric spark so caused directly impinges on the surface of the workpiece. It takes only a few micro seconds to complete the cycle & the spark discharge hit the anode (workpiece) with considerable force & velocity, resulting in the development of a very high temp. (around 10,000°C) on the spot hit by the discharges.

→ This force is the metal to melt & a portion it may be vaporised even. these vaporised these vaporised even. These vaporised or melted particles of the metal are thrown into the gap by the electrostatic & electromagnetic forces, from where they are driven away by the flowing liquid dielectric. The maxm effect of the arc impingement is on the elevated spot on the work piece surface, so they are first to get removed.

→ It should be remembered that
erosion takes place on both, the tool
as well as the workpiece, but the
former is eroded much less as
compared to the latter. It is because
the tool tip is subjected to compressive
forces due to electric & magnetic fields,
resulting in a slower erosion of the metal
from its surface. The rate of metal removal
depends upon the discharge current, duration
of pulse & the rate of pulse repetition.
→ In this system, the gap control is
effected through a servo system. This
maintains constant gap throughout the
operation & senses changes in gap conditions.
The servo system used may be electrical
or Hydraulic.
→ The tool (electrode) used is generally
made of brass or copper, although some
other materials like cast iron, tungsten,
graphite, steel, alloy of silver etc.
have also been used in some machining
operations. The tool material selected
have a high wear resistance, ensure
faster material removal, should be a
good electrical conductor, & tooling cost
should reduce due to its use. The
use of dielectric provided two main
advantages.
(i) It acts as a vehicle to drive away the
chip & thus prevents them from sticking
to the surface of the tool.

(ii) It helps in increasing the rate of metal removal.

→ For work material, the important point is that any material which is an electrical conductor can be machined through this process.

* Advantages of EDM.

(i) Enables high accuracy on tools & dies, because they can be machined in as hard condition.

(ii) Even highly delicate sections & weak materials can be machined without any fear distortion.

(iii) Irrespective of its hardness or strength, any material, which is an electrical conductor, can be machined.

(iv) Any shape that can be imparted to the tool can be reproduced.

(v) Fine holes can be easily drilled.

(vi) It is a quicker process.

* Disadvantages of EDM.

(i) Profile machining of complex contours is not possible at required tolerancy

(ii) Machining times, tool long.

(iii) Excessive tool wear

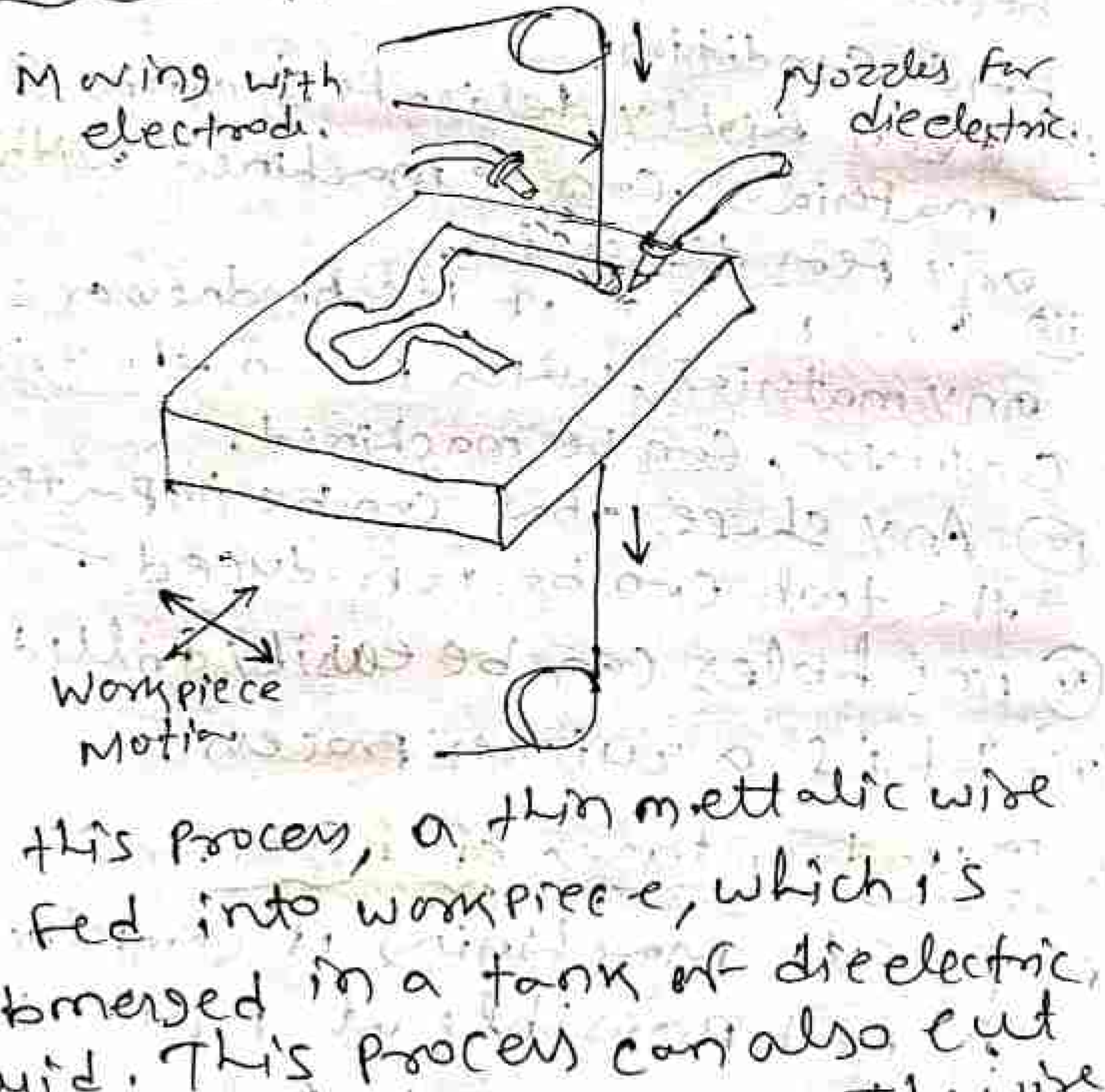
(iv) High specific power consumption.

(v) Machining heats the workpiece considerably & hence change in surface & metallurgical properties.

* Application of EDM.

→ Resharpening of cutting tools & broaches, trepanning of holes with straight or curved axes, machining of cavities for dies & remachining of die cavities without annealing.

* Wire cut EDM :-



→ In this process, a thin mettalic wire is fed into workpiece, which is submersed in a tank of dieelectric fluid. This process can also cut plates as thin as 300 mm. The wire which a constantly fed from a speed is held between upper & lower diamond guides. The guides are usually CNC controlling.

→ The wire-cut EDM uses a very thin wire 0.02 to 0.3 mm in diameter as an electrode & machines a workpiece with electrical discharge like a bandsaw by moving either the workpiece or wire. Erosion of the metal utilizing the phenomenon of spark discharge is the very same as in conventional EDM.

→ Wire cut EDM machine basically consists of a machine proper composed of a workpiece contour movement control unit, workpiece mounting table & wire drive section for accurately moving the wire at constant tension, a machining power supply which applies electrical energy to the wire electrode, & a unit which supplies a dielectric fluid (distilled water) with constant specific resistance.

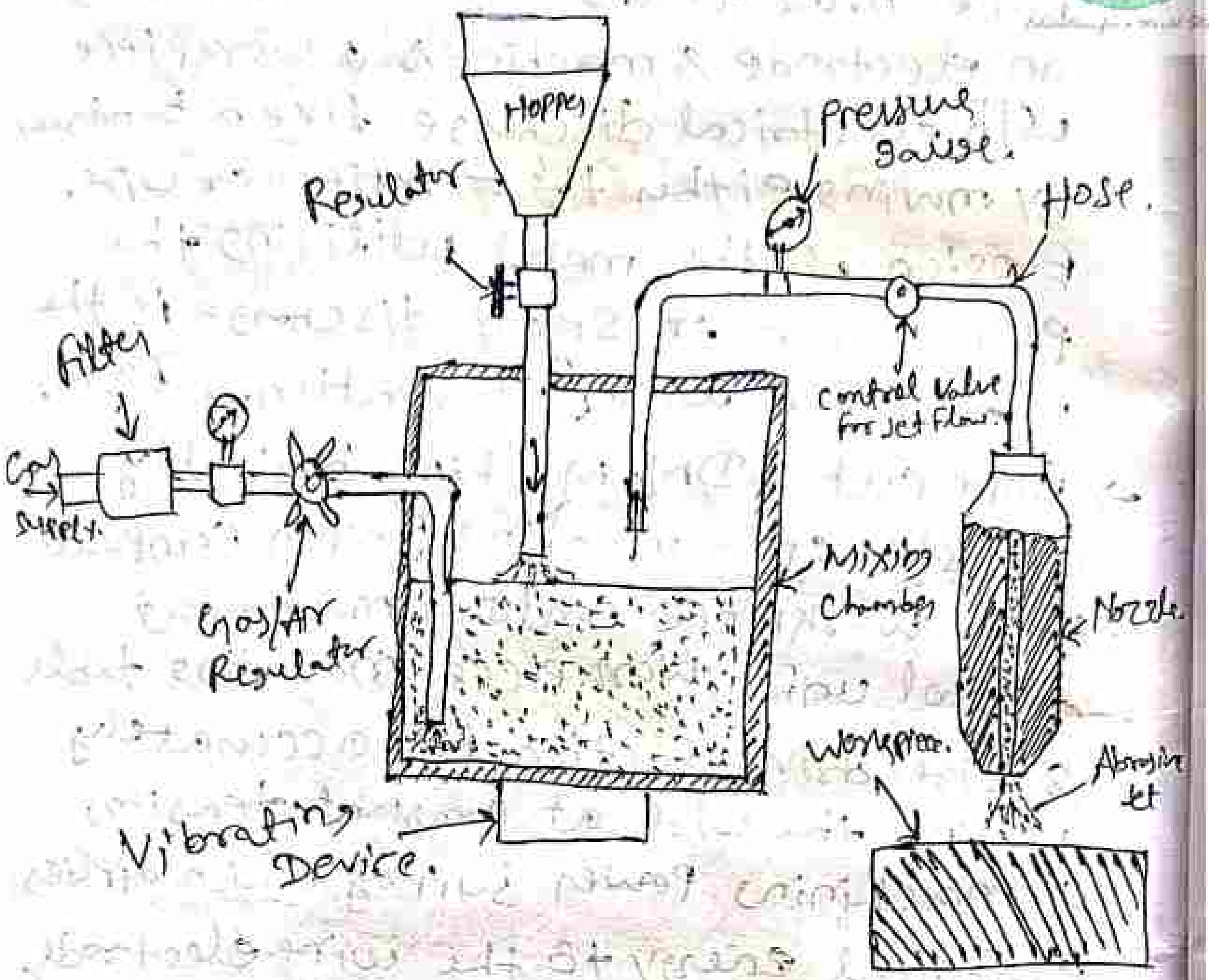
* Application of WEDM:

(i) Used for pattern & die making industries.
(ii) Cutting intricate shape.
(iii) Electric & aerospace industries.
(iv) Cutting of gears, punches.
(v) Micro machining.

* Advantages of WEDM:

→ High MRR.

* Abrasive Jet Machining :-



→ This process consists of directing a steam of fine abrasive grains, mixed with compressed air or some other gas at high pressure, through a nozzle on to the surface of the work piece to be machined. These particles impinge on the work surface at high speed & the erosion caused by their impact enables the removal of metal.

→ Fine grained abrasive powder is filled in a vibrating chamber, called 'mixing chamber'. The gas or air at high pressure is forced into this chamber, the pressure of the gas varying from 2 kg/cm² to 8.5 kg/cm².

→ For normal machining work the nozzle can be manipulated by hand, but for cutting critical shapes or precision cutting along an intricate contour either the workpiece or the nozzle is mounted on suitable fixtures & moved by means of well designed mechanism along a predetermined path, such as cams, Pantographs. etc.

→ An AJM machine the abrasive particles are contained in a suitable holding device, like a hopper, & fed into the mixing chamber. A regulator is incorporated in the line to control the flow of abrasive particles, compressed air or high pressure gas is supplied to the mixing chamber through a pipe line. This pipe line carries a pressure gauge & a regulator to control the gas flow & its pressure.

→ The mixing chamber, carrying the abrasive particles, is vibrated & the amplitude of these vibrations controls the flow of abrasive particles. These particles mix in the gas steam, travel further through a hose & finally pass through the nozzle at a considerably high speed. This outgoing high speed stream of the mixture of gas & abrasive particles is known as abrasive jet.

→ The abrasive commonly used include aluminium oxide, silicone carbide, sodium bi-carbonate, dolomite & small size glass beads.

* Aluminium oxide → general purpose machining, grooving & cutting.
* Silicon carbide → for faster machining of hard material.
* Sodium bicarbonate → for fine finishing work.
* Dolomite → eatching & light cleaning.
* Glass beads → fine deburring & light polishing.

→ The nozzle used are made of Tungsten carbide or synthetic sapphire because the nozzles are required to be highly abrasion resistant.

* Advantages of AJM.

(i) Intricate cavities & holes of any shape can be machined in materials of any hardness.
(ii) Brittle materials of thin sections can be easily machined.
(iii) Low capital investment required.
(iv) There is no direct contact between the tool & workpiece.
(v) Amount of heat generated is not appreciable.

* Disadvantages of AJM.

(i) It is not suitable for machining of ductile materials. ~~of any hardness~~
(ii) Material removal is slow.
(iii) Machining accuracy is relatively poorer.
(iv) There is always a danger of abrasive particles getting embeded in the work material. Hence, cleaning needs to be necessarily done after the operation.
(v) The abrasive powder used in the process cannot be reclaimed or reused.

* Application of AJM :-

(i) Fine drilling & microwelding.
(ii) Aperture drilling for electronic microscopes.
(iii) Machining of semiconductors.

(iv) Machining of Intricate profiles on hard & fragile materials.

(v) Frosting & abrading of glass articles.

Process Parameters:

(i) Abrasive.
- Material - Al_2O_3 / SiC / glass beads.
- Shape - Irregular / Spherical.
- Size - (10-50) µm
- Mass Flow rate - (2-20) gm/min.

(ii) Carrier gas.
- Composition - Air, CO_2
- Density - Air - 1.3 kg/m3.
- Velocity - (500-700) m/s.
- Pressure - (2-10) bar

(iii) Abrasive Jet.
- velocity - (100-300) m/s.
- Mixing ratio.
- Stand-off distance - (0.5~5) mm.

(iv) Nozzle.
- Material - WC
- Diameter - (0.2~0.8) mm.
- Life - (10-300) hours.